A STUDY OF THE TUNGSTEN POTENTIAL IN BOULDER COUNTY, COLO.

BY CARL BELSER

* * * * * * * * * **Information Circular 7721-**

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by

Carl Belser[1]

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INTRODUCTION AND SUMMARY

Approximately 30 million pounds of tungsten trioxide in the form of ferberite concentrates have been shipped from Boulder County. Since 1940, the production has varied considerably, being affected by the emergency needs of World War II and the Korean conflict. During World War II, attempts to stimulate production were made by the Metals Reserve Company by stabilizing the price for a specified period, the Reconstruction Finance Corporation by small mining development loans, and the Bureau of Mines and the Geological Survey, who cooperatively explored some of the district by surface and underground core drilling. During the Korean conflict and continuing through the first half of 1954, tungsten production was being stimulated by a Government-gauranteed price and by financial assistance loans under the Defense Production Act of 1950 to qualified operators of properties that have merited exploration. This combined program has increased production in Boulder County from about 1,900 pounds in 1949 to an estimated 383,000 pounds of tungsten trioxide in 1953. The 1953 production came from 67 properties.

One of the problems confronting producers is the need for improved beneficiation methods. Ores from the area have not been amenable to flotation concentration and gravity methods have resulted in poor recovery, often less than 70 percent.

Ferberite ores in Boulder County locally are classified as soft or horn types. Soft ores are usually higher in grade and are amenable to gravity concentration. Horn ore consists of an intimate association of fine-grained ferberite and quartz, which up to the present time has been concentrated, but with a low recovery. Horn ore occurs both singly and with soft ore. Ores containing appreciable quantities of horn usually are not accepted by concentrating mills.

The current efforts by industry, which are materially benefiting the Nation in its goal for adequate mineral supplies, would be aided considerably if beneficiation methods for ferberite concentration could be improved. Research with this objective is currently being conducted at the Salt Lake Experiment Station, Region III, Bureau of Mines.

In order to justify this research, a survey was made of the properties in the Boulder County tungsten-producing district to establish the probable ore potential. This paper reports the results of the ore-reserve survey. To indicate the relative importance of the district, careful estimates of past production were compiled from data assembled in March and April 1954.

Total indicated and inferred reserves of soft ore, which is amenable to gravity concentration, are estimated as 492,435 tons containing 0.426 percent WO_3 or 210,017 units. Total indicated and inferred reserves of horn ore, which is not readily amenable to gravity concentration, are estimated as 207,318 tons containing 0.714 percent WO_3 or 148,725 units. Total reserves are estimated as 699,753 tons containing 0.513 percent WO_3 or 358,742 units. The horn ore estimates are lower than would be expected because they generally have not been amenable to concentration and consequently have not been explored or developed. It is probable that if the metallurgy of horn ore were improved, a considerably greater reserve of this type of ore would become available.

ACKNOWLEDGMENT

Appreciation is expressed to the Boulder County property owners and operators who, without exception, cooperated in providing data for this report.

HISTORY AND PRODUCTION

Tungsten was first identified as an element by the Swedish chemist Scheele in 1781, and Robert Musket obtained a British patent for the use of tungsten in hardening steel in 1859.

Towner, a gold miner in Boulder County, excavated a small hole near the site of the old Conger shaft in the 1860's. The apparently "worthless black iron" was noted by many later prospectors, among them Samuel B. Conger and Nelson Wannamaker.

The Manual of Mineralogy and Petrography by Dana, printed in 1891, lists the Golden Queen mine at Ward as containing scheelite. J. H. Knight, a successful Boulder County miner recognized the minerals hubnerite and wolframite in mines between Ward and Gold Lake in the early 1890's. His display of tungsten ores at the Paris Universal Exposition in 1899 caused considerable interest to be shown in Boulder County deposits.

A Mr. Beddig of Germany probably mined the first tungsten ore in Boulder County from the Beddick (or Beddig) vein; he was closely followed by Conger and Wannamaker who reportedly mined 40 tons in 1900 from the nearby Conger vein. Morris Jones started the Great Western Exploration & Reduction Co. in 1901; this company later became part of the Primos Mining Co. The Wolf Tongue Mining Co. began operations in the area in 1904. Most of the favorable tungsten-bearing land was owned or located by 1905.

Production in 1900 was 2,760 units valued at about $1.25 a unit (Appendix I). Maximum production of 162,420 units was reached in 1917 (8);[2] the estimated 1953 production was 19,143 units. Through 1948 about 20 percent of the total tungsten production in the United States came from Boulder County.

The General Services Administration of the Federal Government has been authorized to purchase tungsten at the base price of $63.00 per short ton unit (dry weight) of contained tungsten trioxide up to July 1, 1958, or until 3,000,000 short-ton units have been delivered to specified purchasing depots and accepted by the Government. Under this program, local custom mills in Boulder County pay $23.00 a unit for 1 percent acceptable ore and $27.00 a unit for 2 percent acceptable ore, in accordance with the schedule shown in Appendix II.

LOCATION AND PHYSICAL FEATURES

The main tungsten-bearing district in Boulder County, which overlaps into Gilpin County, is a narrow belt 9-1/2 miles long and 4-1/2 miles wide trending southwest from Arkansas Mountain, 4 miles west of Boulder, to Sherwood Flats, 1-1/2 miles northwest of Nederland (fig. 1). A few small tungsten mines and several potentially important horn ore deposits lie outside of the main district.

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[2] Underlined numbers in parentheses refer to items in the Bibliography at the end of this report.

State Highway 119 follows Boulder Canyon from Boulder to Nederland, a distance of 18 miles, where it connects with State Highway 160. Good access roads extend from these two highways to the principal mines. The nearest railroad loading facilities are those of the Denver and Rio Grande Western Railroad at Rollinsville, 4 miles south of Nederland. Boulder, the nearest supply point, is served by the Union Pacific and Colorado & Southern Railroads. Electric power is available throughout the district from service lines of the Public Service Co. of Colorado. A schedule of the electric energy rates is given in Appendix III.

The Nederland area comprises a gently rising upland extending from the foothills of the Front Range on the east to the steeper slopes on the west. It is an area of rounded mountain tops and flat ridges separated by narrow valleys and deep canyons. Altitudes vary from 6,000 to 9,500 feet, and the climate, although somewhat severe in winter, permits year around mine operation. Abundant native timber is available, which is suitable for most mine use.

LABOR AND LIVING CONDITIONS

Adequate labor is available from Nederland and Boulder. Prevailing wages are from $1.25 to $1.80 an hour. Several houses are available in Nederland, Tungsten, and other camps throughout the tungsten district, but most of the mine-operating personnel live in Boulder and drive to and from work.

PROPERTY OWNERSHIP

Property is held by over 500 patented mining claims, several hundred unpatented claims, and about 6,000 acres of patented agriculture land on which the mineral rights have been retained.

A booklet sponsored by the Boulder County Metal Mining Asssociation in 1918 reported 3 refineries, 22 concentrating mills, and hundreds of mines equipped for operation. In 1953 there were 4 scavenger dump plants, a magnetic-separation plant, a synthetic scheelite plant, 8 gravity concentration plants, and 67 producing mines. The principal tungsten mine owners are listed in table 1.

Many mining properties not listed in table 1 contain one or more claims. Three of the principal land owners, holding about 3,795 acres on which more than half of the past production of the district has been made, express little interest in leasing or operating their properties for producing tungsten.

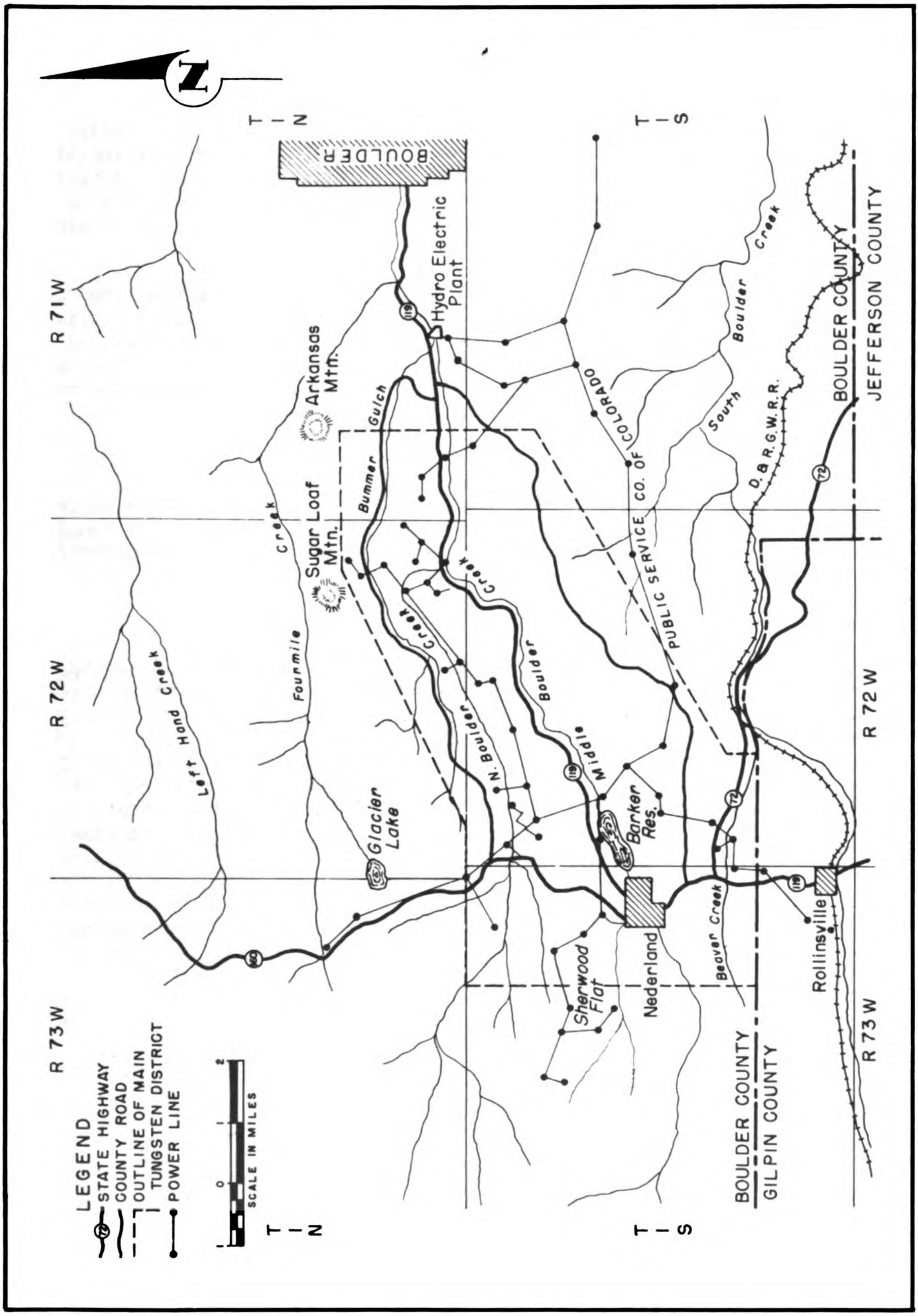

Figure 1. - Main tungsten district of Boulder County, Colo.

TABLE 1. - List of principal mine owners, Boulder County, Colo.

Mine owner	No. of patented claims	Acres of patented agricultural land	Approximate total acres
Vanadium Corp. of America	58	1,228.7	1,576.7
Hetzer Mines, Inc.	98	340.0	830.0
Colorado Tungsten Corp.	7	719.5	752.5
Clark Minerals, Inc.	5	267.0	303.0
Platt Rogers, estate	-	1,469.5	1,469.5
Juanita Clark	17	-	850.0
George Cowdery	39	-	315.0
Elmer Hetzer	5	225.0	255.0
W. L. and Guy Tanner	21	-	130.0
A. J. Critz	11	-	55.0
G. H. Teal	13	-	80.0
Shattuck Chemical Co.	13	-	80.0
C. E. Wolcott	10	-	50.0
Joseph Rafter	7	-	60.0
Ernest Bonelli	16	-	80.0
George Jump	5	-	30.0
A. B. Pace	5	-	30.0
Boulder County	165(est.)	-	990.0

GEOLOGY AND ORE DEPOSITS

According to Lovering (2,5,6), about three-fourths of the tungsten district lies within a small batholith of pre-Cambrian gneissic quartz-monzonite that extends from 1 mile west of Boulder to the village of Tungsten and is known as Boulder Creek granite. The remaining one-fourth of the district bordering the batholith to the west contains pre-Cambrian metamorphic rocks, principally quartz-biotite-schist of the Idaho Springs formation, which has been intruded by aplite and pegmatite masses related to the batholith. These pre-Cambrian rocks are cut by dikes of late Cretaceous or early Tertiary age consisting of predominately hornblende monzonite porphyry and hornblende diorite porphyry in the western half of the district and biotite porphyry with biotite breccia in the eastern part. Two major fracture systems stand out, the first, trending northwest contains mostly barren veins and the second, trending northeast contains most of the productive tungsten veins. The northwest-trending faults, locally called breccia reefs, can be traced for many miles and are related to ore deposition.

The tungsten veins generally are narrow and irregular with small ore shoots ranging from a few inches to 3 feet in width; in a few places veins up to 16 feet wide have been mined. Most of the ore consists of ferberite disseminated through quartz; quartz constitutes the principal vein material. Some scheelite occurs in various ores of the district, but no commercial deposits of scheelite are known. Hubnerite has been found as a minor constituent in the Quay and Golden Queen mines.

Ore has been mined over a vertical range of 700 feet throughout the district, although most of the individual ore shoots have been followed to a depth of less than 100 feet from the surface. Probably many concealed ore shoots exist that do not outcrop at the surface.

The Ore

Ore mined is generally classified by miners and operators as soft or horn. Soft ore, consisting of friable, coarsely crystalline ferberite as a filling in brecciated country rock and vein quartz, is amenable to gravity concentration.

Horn ore is comprised of extremely fine grained crystals of ferberite disseminated through contemporaneous fine-grained quartz or hornstone; it occurs throughout the district but is more common in the eastern part. Horn ore is difficult to concentrate; it requires extremely fine grinding, which causes wear on equipment and results in excessive sliming. Ore predominantly of the horn type has been slightly upgraded by gravity concentration methods but with very low recovery.

MINE DEVELOPMENT

Development in the tungsten district includes about 23,000 feet of shafts and prospect pits, 12,000 feet of adits, 80,000 feet of drifts and crosscuts, and 20,000 feet of surface trenching. Among the deeper shafts, all of which are over 300 feet deep, are the April Fool, Beddig, Clyde, Cold Spring, Conger, Cross, Good Friday, Mammoth, Oregon, and Tungsten. At least 88 shafts have been sunk over 100 feet, and there are several hundred prospect-type shafts. Adits have been used to develop a number of veins and some of the principal adits are: Clark, Conger, Eureka, Good Friday, Greenhorn, Halfway, Long, Luckie 2, Prospect, Roosevelt, Vasco 5, and Windy. The Conger has been the largest producer and is the most extensively developed mine in the district.

Exploration and development work in tungsten mines has been kept at a minimum and, in general, mines are in poor condition. Several publications are given as references at the end of this report on the tungsten ore deposits and mines in Boulder County.

MINING METHODS

Early day development was done with hand tools. Present mining operations use gasoline or electric-powered hoisting equipment, compressors, and pneumatic drills. Headframes are generally of minimum height and relatively inexpensive. The Conger mine shaft utilizes a cage, the Cold Spring a skip on inclined track, and all other shafts use only buckets on wooden skids. Timbering is done mostly with both framed and unframed native timber. Some shafts require solid cribbing in weak spots. Mechanical mucking machines are used in only two of the mines.

Stoping is done by open, cut-and-fill, shrinkage, and underhand methods. In general, production comes from narrow veins, and workings are kept to a minimum size. Cut-and-fill and shrinkage stope methods are used in most of the mines. As a whole, the mines do not yield large tonnages and elaborate operations are not required.

ORE RESERVES

The ferberite ore deposits of Boulder County usually are mined out as developed. The horn type deposits have not proved profitable and, therefore, have not been developed extensively. An attempt, resulting in this paper, was made to estimate these ore reserves in order to justify beneficiation research. Estimates were based on carefully evaluated statements from past and present operators, and from Government and private reports for the area (9).

Of the several hundred tungsten mines in Boulder County, many are shown on figures 2 and 3 and 237 are listed in Appendix IV of this report; 109 of these mines are credited with reserves as ore in place, in stope fills, dumps, old tailing ponds, and in residual or "float" beds. Low-grade ore in dumps and float beds is included because scavenger mining and milling operations have been carried on

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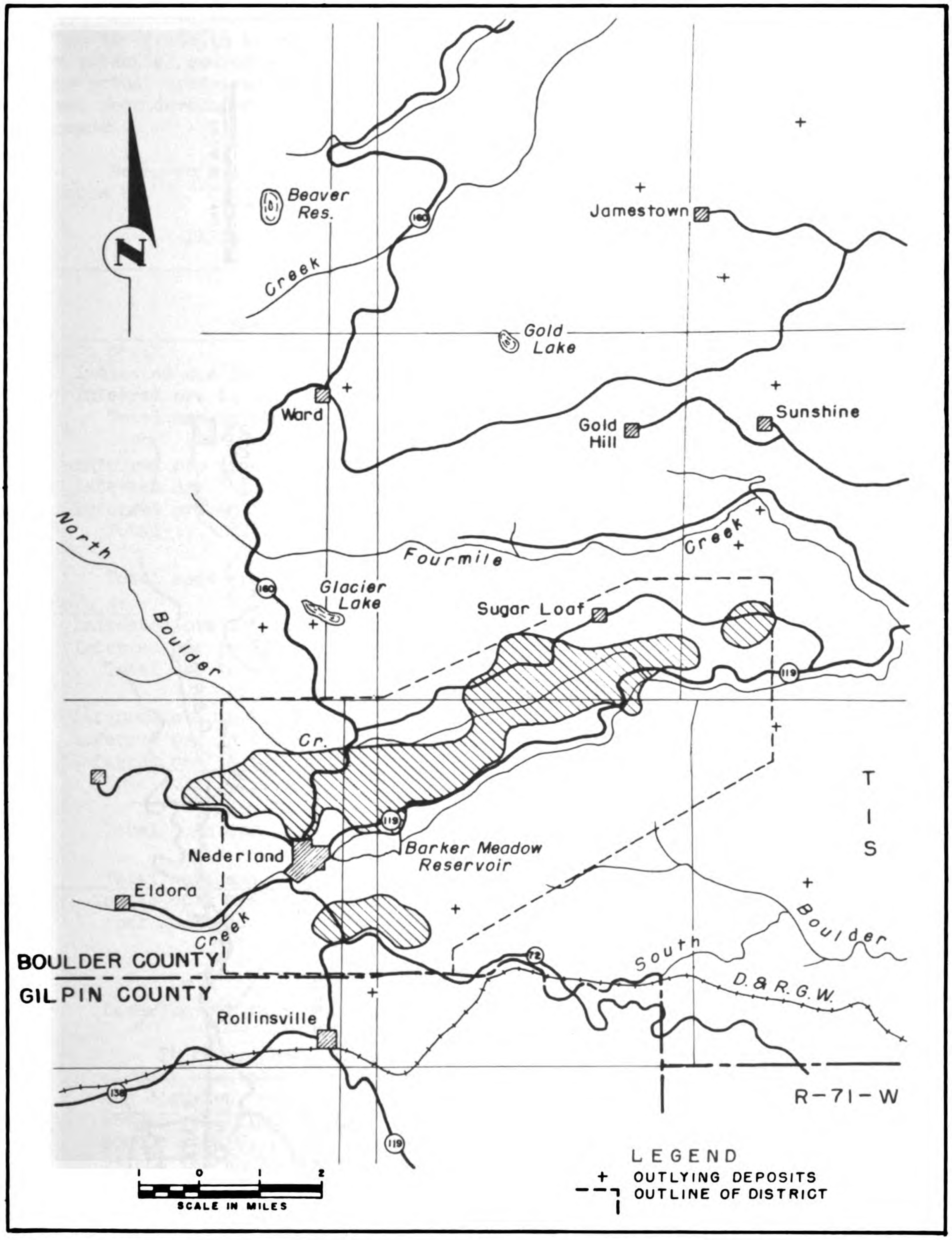

Figure 2. - Location of principal soft tungsten ore areas.

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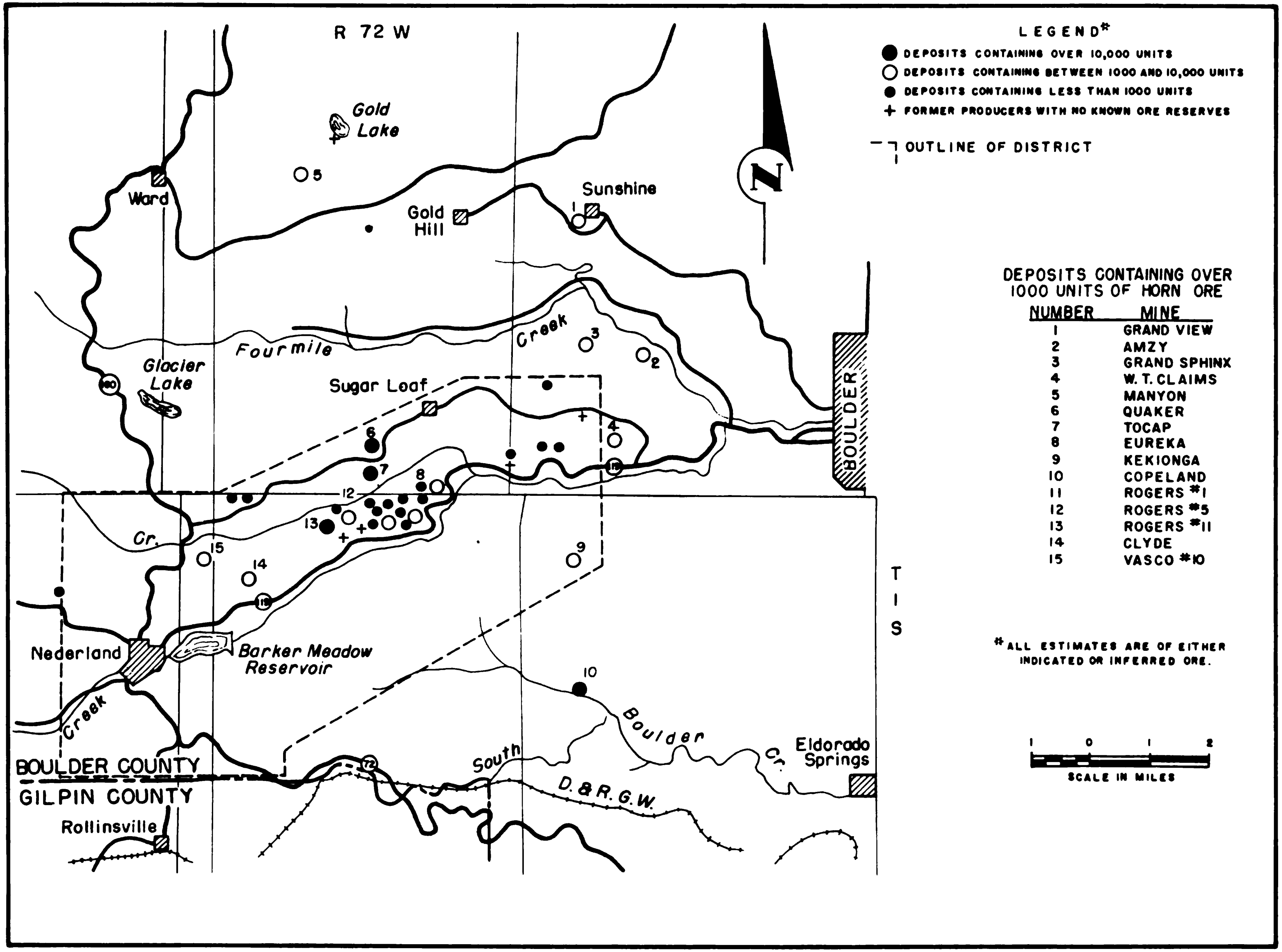

Figure 3. - Location of principal known horn tungsten ore deposits.

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successfully, with costs being as low as $2.00 a ton. Average milling costs in 1953 are estimated at $12.00 per ton of crude ore. Some of the stope fills are too low-grade to be processed profitably by present milling methods, but they are a potential source of tungsten if milling methods are improved. Reserves are given by actual grade and not as recovered tungsten trioxide. Horn-type ore bodies have not been developed or sampled enough to allow adequate evaluation of quantity and grade.

Reserves are summarized as indicated or inferred of both soft or horn ores in table 2.

TABLE 2. - Estimated tungsten ore reserves in Boulder County

Reserves	Tons	Grade, percent WO_3	Units of WO_3	Number of properties
Soft ore:				
Indicated ore in place	8,598	3.358	28,874	9
Inferred ore in place	53,346	2.153	114,953	40
Total ore in place	61,944	2.320	143,827	
Inferred ore in stope fills	63,725	.502	32,000	12
Inferred ore in dumps	67,600	.206	13,940	34
Inferred ore in float-beds	299,166	.068	20,250	4
Total	430,489	.154	66,190	
Total soft ore	492,435	.426	210,017	
Horn ore:				
Indicated ore in place		2.973		2
Inferred ore in place		.715		23
Total ore in place	1/ 185,518	.766	1/ 142,129	
Inferred ore in stope fills		.500		1
Inferred ore in dumps		.285		15
Inferred ore in tailings		.500		1
Total	1/ 21,800	.303	1/ 6,600	
Total horn ore	207,318	.717	148,725	
Total soft and horn ore	699,753	.513	358,742	

1/ Totals only are given to avoid revealing confidential information from individual sources.

FUTURE EXPLORATION

Lovering (6) in a report on the district in 1940 writes:

> It seems probable that most of the tungsten ore of the district has already been mined. Many undiscovered ore shoots may still be present in the district, but the cost of finding them will be considerable. Under normal conditions of exploration, and with the price of tungsten about $20.00 a unit, it may be expected that the district will continue to provide a few hundred tons of concentrate a year for many years to come. Even with the stimulus of high prices it is doubtful if the annual production will reach 1,000 tons (concentrate unless an elaborate campaign of geologic exploration and diamond drilling, whose success would be uncertain, is carried forward.

After 14 years Lovering's statement still appears accurate. During World War II, stimulus to tungsten mining in the district was provided by granting Reconstruction Finance Corporation loans, stabilizing the price for a definite period, and by a diamond drilling program operated by the Bureau of Mines with geologic guidance from the Federal Geological Survey. In 1950, stimulus was provided by granting loans through the Defense Production Act of 1950 and by a greatly increased long term, guaranteed price.

These stimuli have affected production of tungsten - production being about 726 tons in 1940 when tungsten was valued at $18.00 a unit, gradually decreasing to almost nothing in 1949, and rising to about 300 tons in 1953 when the price for domestically produced tungsten was and still is $63.00 a unit.

Most of the veins in the Nederland region have favorable aspects when considering exploration. However, the occurrence of lenticular ore shoots generally can not be predetermined. Several veins only a fraction of an inch thick have, when followed, increased in size and become large ore shoots. Exploration for this type of mineral deposit is uncertain and costly.

If metallurgical research now being conducted on the horn ores of the district proves successful, exploration to determine the extent, both laterally and in depth, of many of the veins containing this type of ore is warranted.

Future exploration can be done by diamond drilling, sinking, drifting, raising, and surface trenching. Short diamond-drill holes can be used to advantage in probing for nearby ore shoots, and longer holes can be drilled to find new veins, extensions of veins, and ore bodies cut off by faulting. Sinking, drifting, and raising on veins that have proved productive is the most effective method of exploration. Surface bulldozing in search for new veins might be effective if support of the many property owners could be coordinated.

ORE DRESSING AND CONCENTRATION

Gravity Concentration and Flotation

The first gravity concentration mill for the beneficiation of ferberite ores was operated in Gordon Gulch in 1900 by the Great Western Exploration & Reduction Co., which later became a part of the Primos Mining Co. holdings.

The Black Cloud mill, a gold mill near Salina, was used by the newly formed Wolf Tongue Mining Co. to concentrate tungsten ores in 1904, and during the same year the company acquired the old Caribou mill at Nederland and began purchasing custom ore in 1905. This mill burned in 1927, and the present Wolf Tongue mill was erected on the same site.

The Lakewood mill, which had the doubtful distinction of being the largest 10-stamp mill in the world, was built in 1910 by the Primos Mining Co.

The Boulder Tungsten Production and Vasco mills were erected at Stevens Camp (now Tungsten) in 1915. The Boulder Tungsten Mills, Inc., plant was built on North Boulder Creek in 1941. This mill had the largest capacity and was probably the most efficient of any of the tungsten mills that have been operated in Boulder County.

Since 1900 at least 35 concentrating mills, 2 tungstic acid plants, a synthetic (called artificial) scheelite plant, a ferro-tungsten plant, and a magnetic-separation plant have been operated in the area. All of the mills, with the exception of the Copeland, have been designed to process the soft-type ore and are listed in table 3. (See fig. 4.)

TABLE 3. - Tungsten mills and plants operated in Boulder County

Plant	Location	Figure number	Type
Black Prince	Eagle Rock	-	Gravity c/
Black Swan	Salina	-	Do.
Boulder County	Cardinal	-	Gravity d/
Boulder Tungsten Mills, Inc. ..	Below Lakewood	-	Do.
Boulder Tungsten Production ...	Tungsten	-	Gravity c/
Boyd	Boulder	-	Do.
Clark-Degge	6 miles west of Boulder	-	Do.
Clarasdorf	Clarasdorf	-	Do.
Conger	Sherwood Gulch	-	Do.
Copeland	South Boulder Creek	-	Do.
Cowdery	Beaver Creek	10	Gravity b/
Domino	Eagle Rock	12	Do.
Fansteel	Beaver Creek	-	Gravity c/
Good Friday	Boulder Falls	5	Gravity a/
Grim	Near Eagle Rock	-	Gravity c/
Haynes	Crisman	-	Do.
Herald	Sugar Loaf	11	Gravity b/
Hoosier	North of Nederland	6	Gravity a/
Industrial	Boulder	13	Synthetic scheelite b/
Jump	Gordon Gulch	-	Gravity c/
Lakewood	Lakewood	-	Do.
Long	Gordon Gulch	-	Do.
Mann	Boulder	-	Do.
Marion (Teal)	Bummer Gulch	7	Gravity a/
Lucky Two	Boulder	-	Gravity c/
More	do.	14	Magnetic separation a/
Primos	Gordon Gulch	-	Gravity c/
Rare Metals	Rollinsville	-	Do.
Red Signe	Eagle Rock	-	Do.
Roose	North of Nederland	-	Do.
Schmidt	Northeast of Rollinsville	-	Do.
Joe Smith	Nederland	8	Gravity a/
Sprague	Near Sugar Loaf	-	Gravity c/
Stoddard-Eckley .... (Black Metals Reduction Co.)	Boulder	-	Tungstic acid c/
Sunnyside	Eagle Rock	-	Gravity c/
Tanner	Beaver Creek	-	Do.
Tungsten Products	Boulder	-	Tungstic acid c/
Do.	do.	-	Ferro-tungsten c/
Vasco	Tungsten	-	Gravity c/
Wolf Tongue	Nederland	9	Gravity a/

a/ Operated in 1953.
b/ In condition to operate or under construction.
c/ Dismantled or partly dismantled.
d/ Used for gold-silver-copper-lead-zinc ores only.

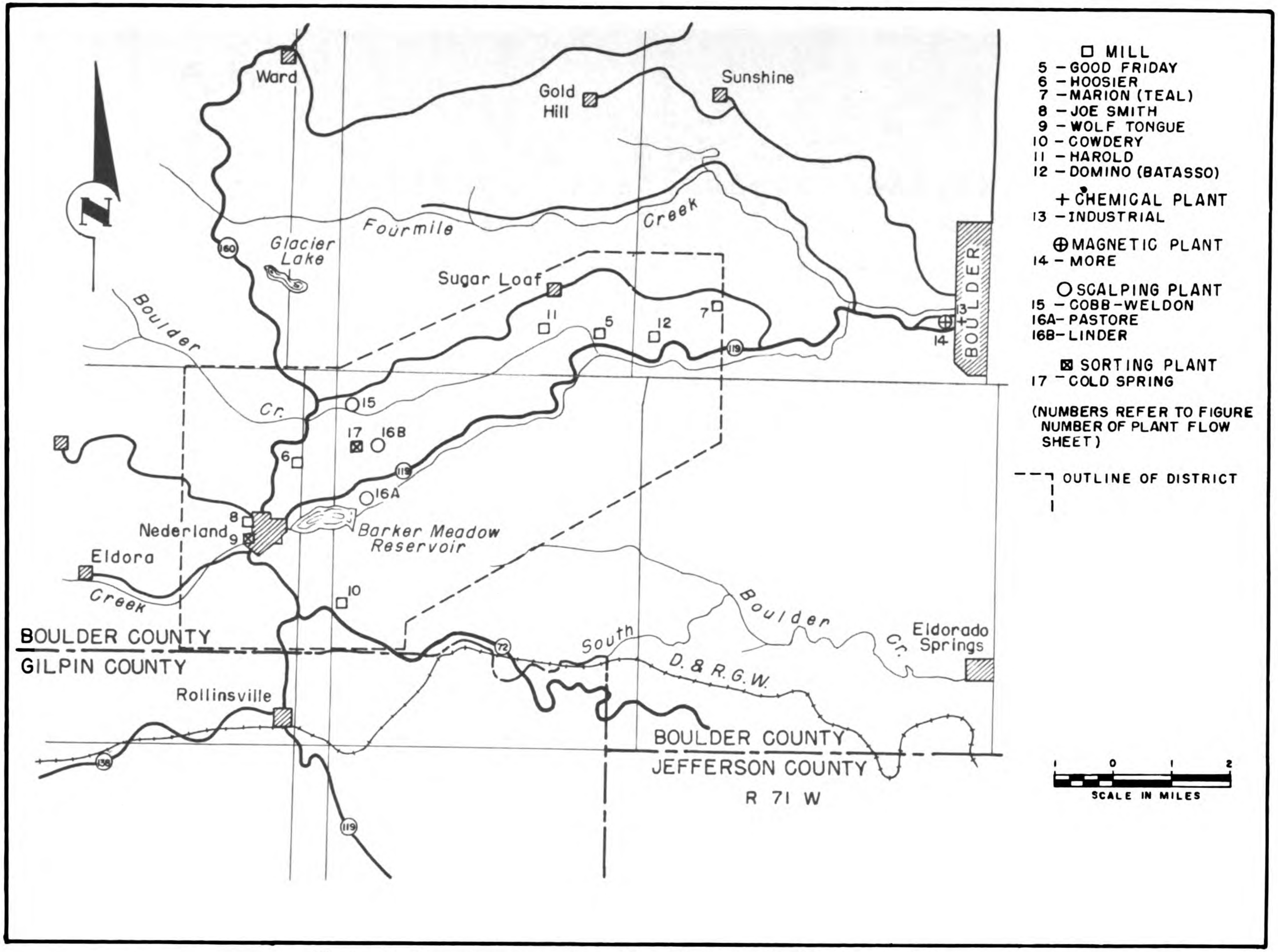

Figure 4. - Location of tungsten mills and plants, Boulder County, Colo.

During 1953, 5 concentrating mills listed in table 4 were in operation, 1 was under construction, and 2 mills that were in operating condition were idle. Flowsheets of these mills are shown in figures 5-12, inclusive.

TABLE 4. - Concentrating mills operated in 1953

Mill	Owner	Capacity per hour	Tonnage treated in 1953	Figure number	Remarks
Good Friday	Jump Mining Co.	2.0	3,600	5	Operated 1 shift per day - short of water.
Hoosier	Johnson Bros. & Prime	1.5	1,300	6	Operated 3 months.
Marion (Teal)	Boulder Tungsten Mines, Inc.	3.0	3,547	7	
Joe Smith	Joseph Smith	2.0	1,100	8	Operated part time.
Wolf Tongue	Hetzer Mines, Inc.	3.0	5,412	9	Operated 1 to 2 shifts per day.
Cowdery	George Cowdery	1.5	-	10	Idle.
Herald	J. McCristy et al.	.85	-	11	Under construction.
Domino	R. Betasso	1.0	-	12	Idle.

Gravity concentration of ferberite ores in the Boulder County district has not been appreciably improved during the past 50 years. Stamps for fine grinding have been replaced by ball, rod, and pebble mills; vanners and Monell slimers, by slime tables; some Hartz-type jigs have been modified to the Ellis type or replaced by pulsator jigs; and spiral sand pumps, by Wilfley-type pumps.

An example of the efficiency obtained in previous mill operation is taken from an old report on the operation of the Boyd mill by V. G. Hills (1). Partial records of the Boyd mill operation during 1906-1907 give the results from milling 19 lots of soft ore. These lots of ore came from the Beddig, Crow No. 4, and Crow No. 18 properties and were reported to have had an average head assay of 7.8 percent WO_3. Recovery averaged 80.65 percent, and the concentrates averaged 61.99 percent WO_3. A test sample from a mine near Boulder Falls, containing some horn ore, assayed 12.43 percent WO_3; the recovery was 56.19 percent, and the concentrates contained 54.49 percent WO_3. A horn-type ore from the east edge of the district was similarly treated in which heads assayed 6.07 percent WO_3, the concentrates 40.37 percent WO_3, and recovery was only 5.03 percent. Hills (1), commenting on this lot, stated: "There was not enough of it saved to pay the cost of running it through the mill. It shows that an engineer depending on his assays, without mill tests, might report favorably on a worthless mine."

It was recognized since the beginning of the district that jigging, sand tabling, and slime tabling (or vanning machine) did not result in a good recovery from the ores as a whole. Usually a rag table unit was added to the mill equipment for additional recovery. The Lakewood mill, with a capacity of 4 tons per hour, had a rag plant containing 120 rag tables in 3 tiers. All the tables were 4 feet wide, and those in the upper tier were 40 feet long.

Flotation was tried in the Wolf Tongue mill to eliminate sulfides. It was also used to float ferberite by Boulder Tungsten Mills, Inc., in 1941. The concentrate made was low-grade, but at that time could be sold to the Government's ore buying depot at Salt Lake City, Utah.

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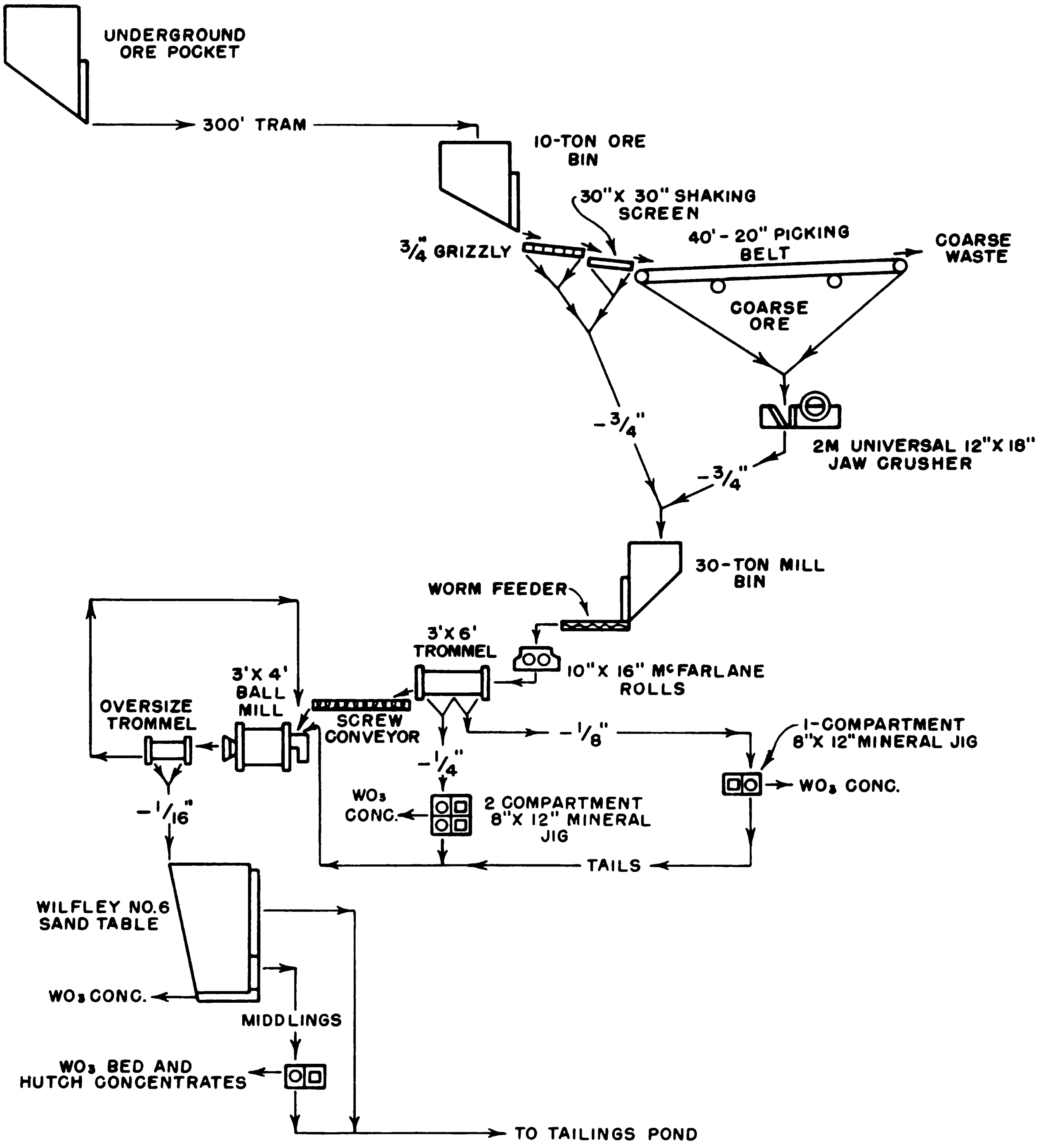


GOOD FRIDAY MILL
(ELECTRIC)

Figure 5. - Flowsheet of Good Friday tungsten mill, Boulder County, Colo.

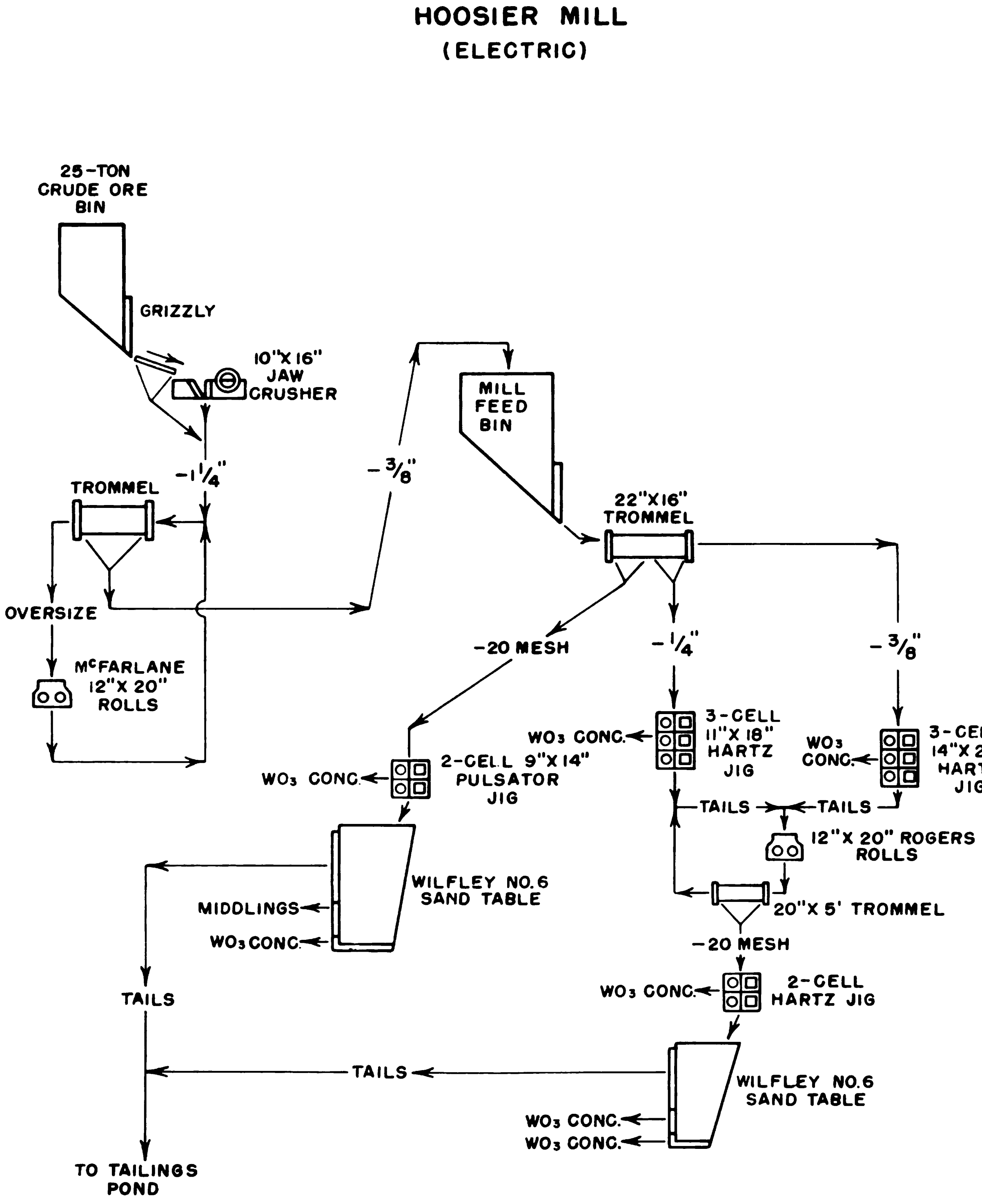


Figure 6. - Flowsheet of the Hoosier tungsten mill, Boulder County, Colo.

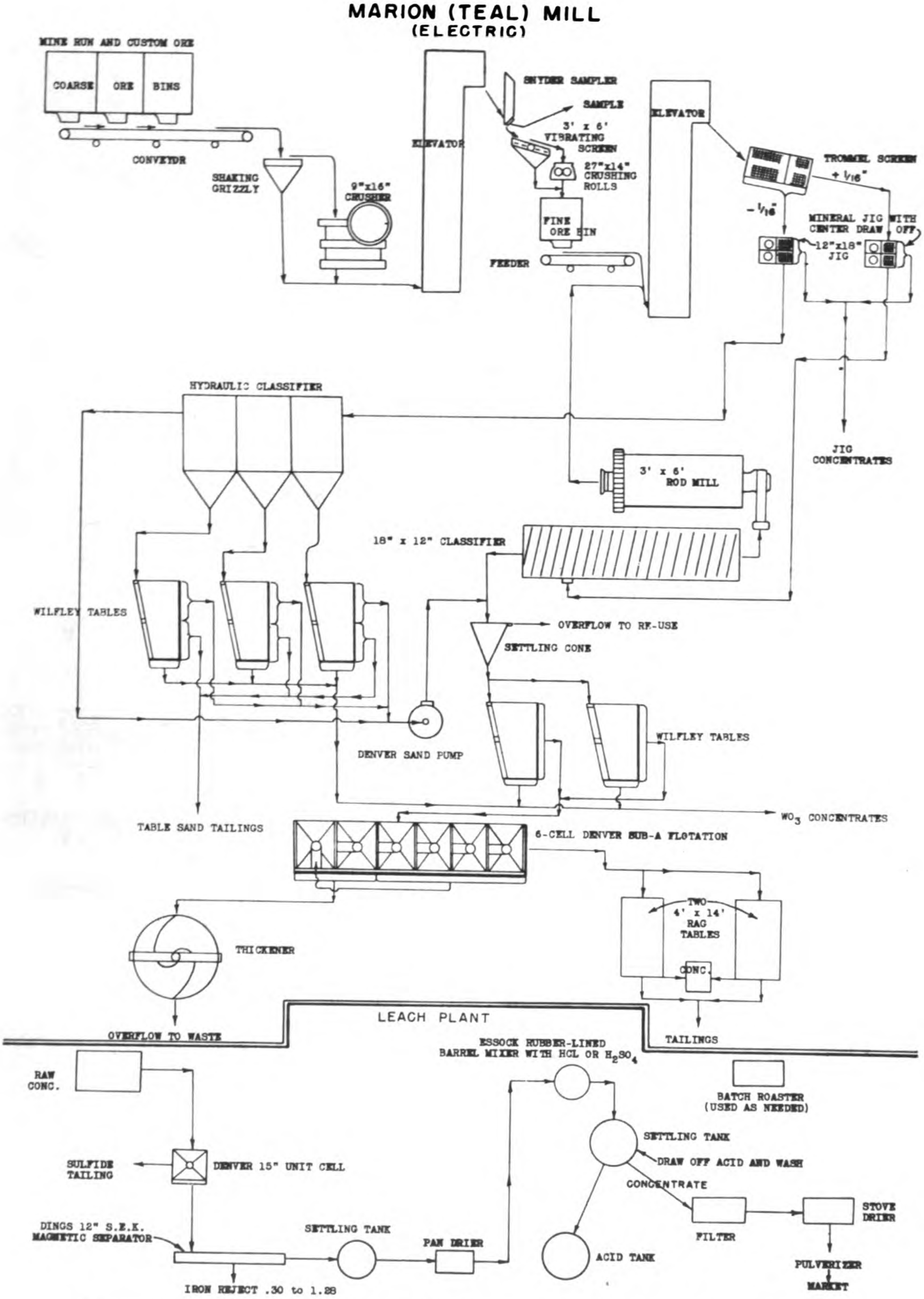
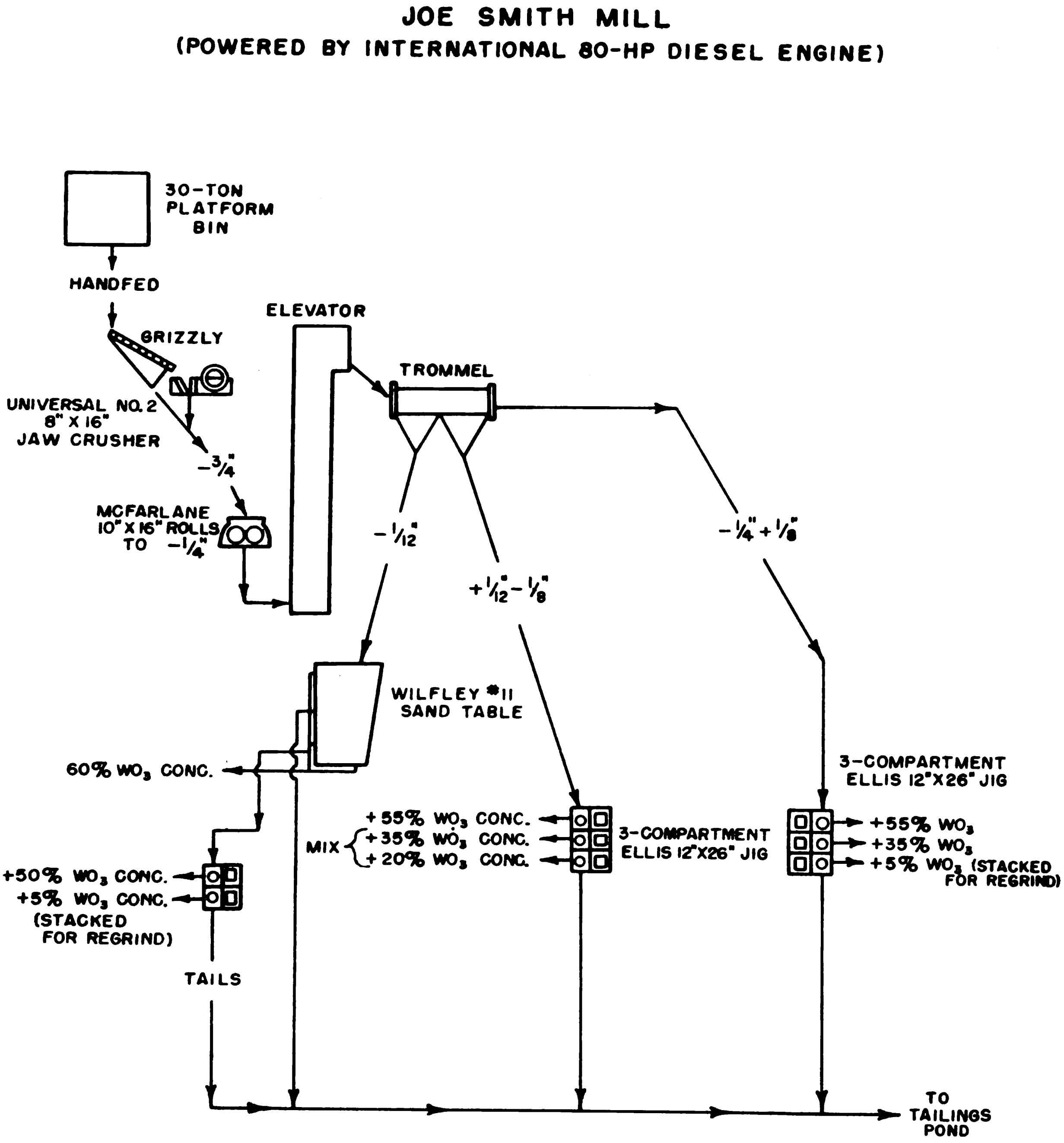


Figure 7. - Flowsheet of the Marion (Teal) tungsten mill, Boulder County, Colo.



RECOVERY TEST ON CONGER ORE (1953)

+55% WO_3 CONCENTRATES	59%
+30% WO_3 MIDDLINGS	14%
TOTAL RECOVERY	73%

Figure 8. - Flowsheet of the Joe Smith tungsten mill, Boulder County, Colo.

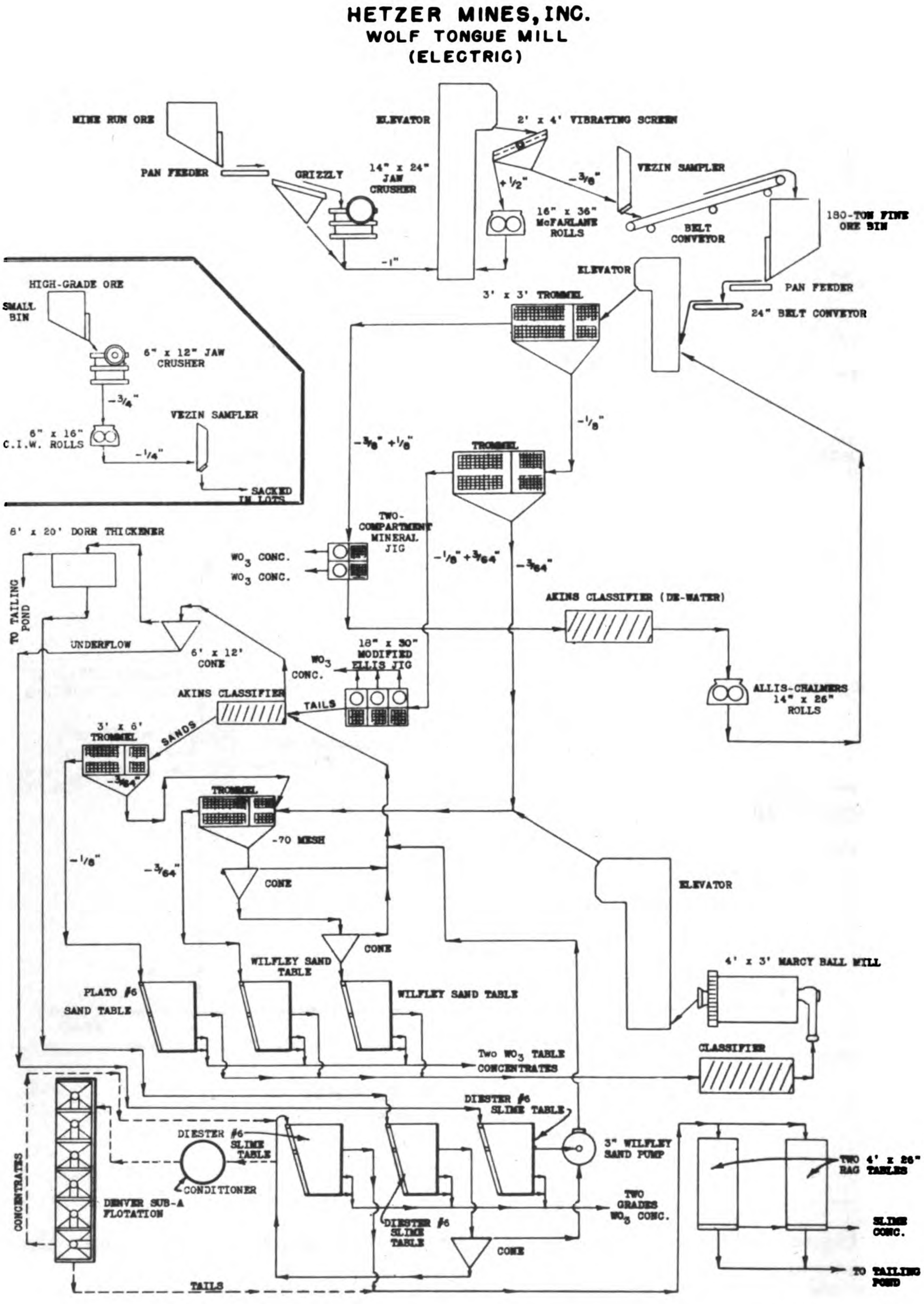


Figure 9. - Flowsheet of the Wolf Tongue tungsten mill, Boulder County, Colo.

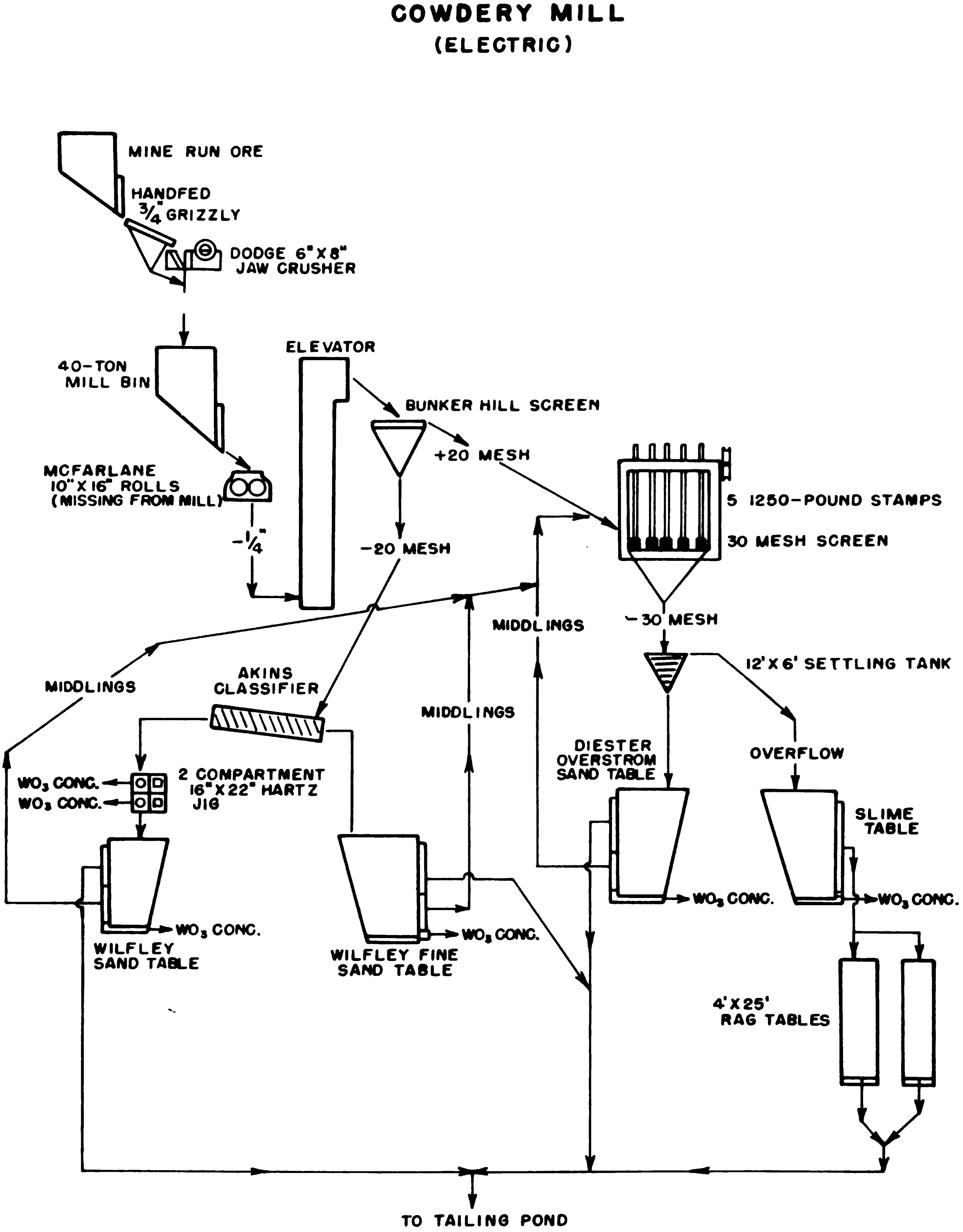
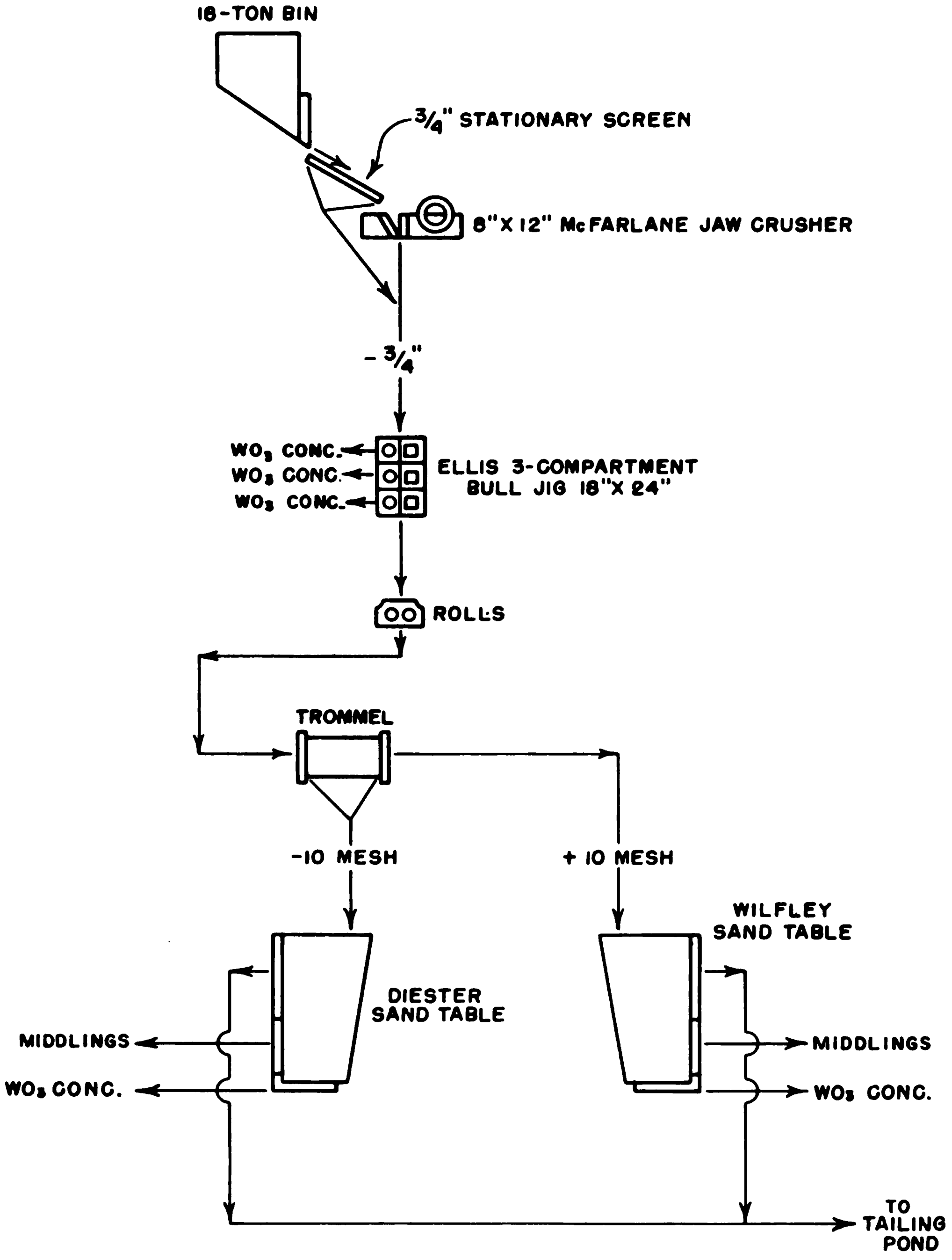


Figure 10. - Flowsheet of the Cowdery tungsten mill, Boulder County, Colo.



HERALD MILL
(POWERED BY GASOLINE ENGINE)

Figure 11. - Flowsheet of the Herald tungsten mill, Boulder County, Colo.

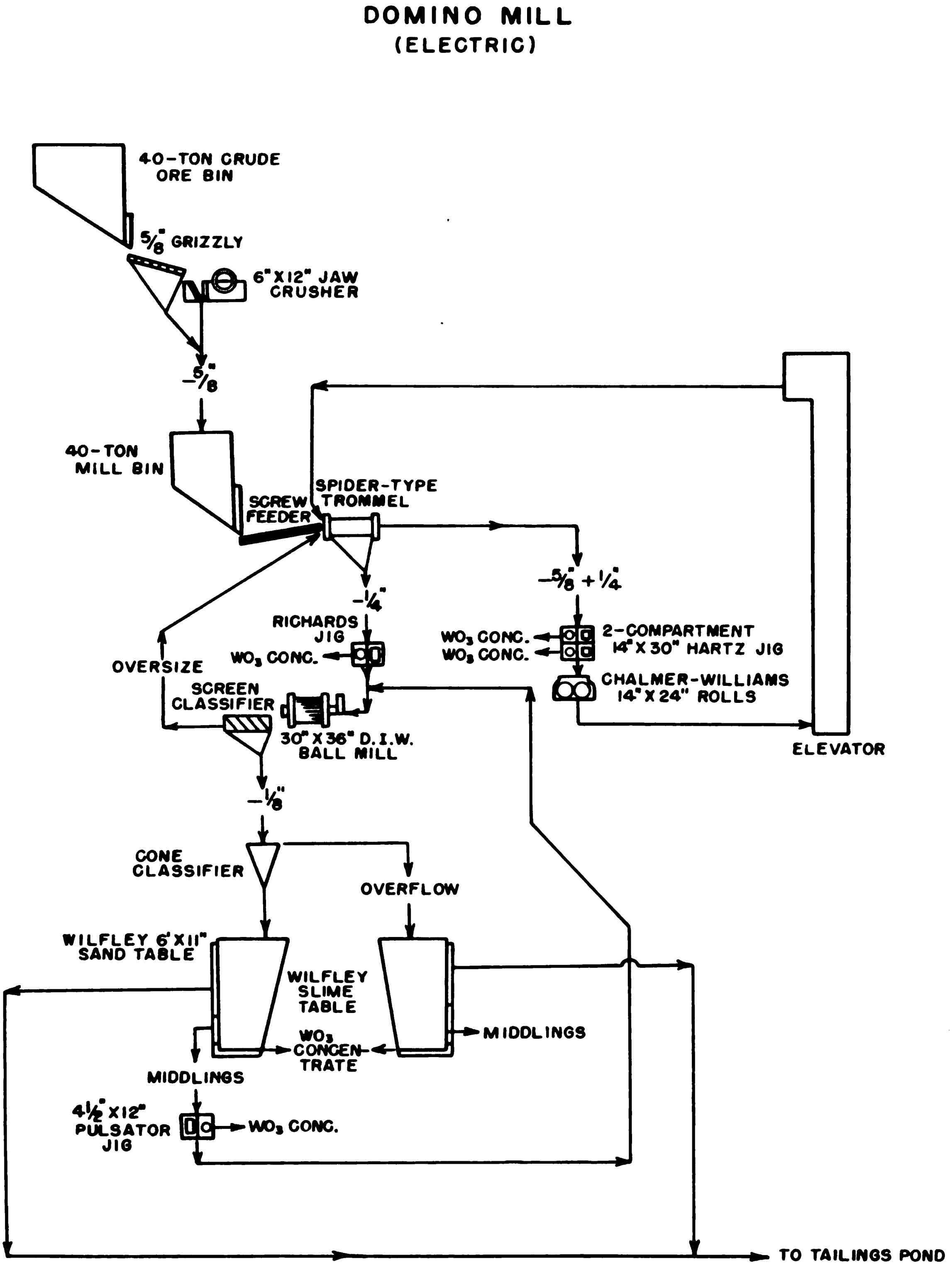


Figure 12. - Flowsheet of the Domino tungsten mill, Boulder County, Colo.

At present both the Wolf Tongue and Marion (Teal) mills have flotation equipment, but the flotation units have been eliminated from the mill circuits.

Ferberite recoveries in the Wolf Tongue and Marion custom mills, run between 70 and 80 percent, depending, in large part, upon the character of the ores treated. Higher recoveries have been made in previous milling when 40 percent WO_3 concentrates could be sold readily. These mill operators have the problem of beneficiating low-grade ores requiring a high ratio of concentration and containing a large percentage of horn ore, which will not concentrate readily; consequently they will not accept knowingly any horn ore for custom milling.

The Marion (Teal) mill and the Hetzer or former Wolf Tongue mill are orderly planned and efficiently managed. Three other mills operated on ore from individual mines. Their flowsheets are simple, and recovery is fair to good because only particular ores that are amenable to gravity concentration are treated.

Chemical Plants

The Black Metals Reduction Co. erected a tungstic-acid plant in Boulder in 1916 which operated through 1918. The Tungsten Products Co. also operated a tungstic-acid plant during World War I. Tungstic acid of good quality was produced in both plants, but losses were high. Combined capacity of the 2 plants was about 800 pounds of 99 percent or better of tungstic acid per day, which was used in making tungsten steel (1). The Industrial Engineering and Supply Co., following a year of experimental work, is now erecting a synthetic scheelite plant in Boulder. This plant will use low-grade ferberite concentrates that can be processed to scheelite containing over 74 percent WO_3. This material can be used to upgrade ferberite concentrates containing less than 55 percent WO_3. Figure 13 is a flowsheet of this synthetic (locally called artificial) scheelite plant. Concentrate cleaning by acid leaching has been employed successfully in the Boulder Tungsten Mills, when it was operating during World War II, and in the Marion (Teal) mill.

Ferro-Tungsten

A ferro-tungsten plant was built in Boulder about 1916 by the Tungsten Products Co. The product, used in making tungsten steel, was made in carbon-lined electric furnaces having a capacity of 4,000 pounds of contained tungsten per day. Operations were discontinued shortly after 1918. The Ferro-Alloy Co. operated a ferro-tungsten plant at Utah Junction, northwest of Denver, during World War I (1).

Magnetic Separation

Magnetic separators were used on some ferberite concentrates during World War I, and one is now used to clean the concentrates in the Marion (Teal) mill.

A. A. More erected a small plant in 1952, which contains both alternating- and direct-current magnets of varying intensities. Results obtained have been encouraging. Eight tons of iron concentrates containing 4 percent WO_3 content from the Cobb-Weldon mill were made into a 53 percent WO_3 concentrate. During 1953 this plant treated about 20 tons of unmarketable concentrate, which was converted into 10 tons of concentrate of acceptable grade. Capacity is 120 pounds an hour. A flowsheet of the More plant is shown on figure 14.

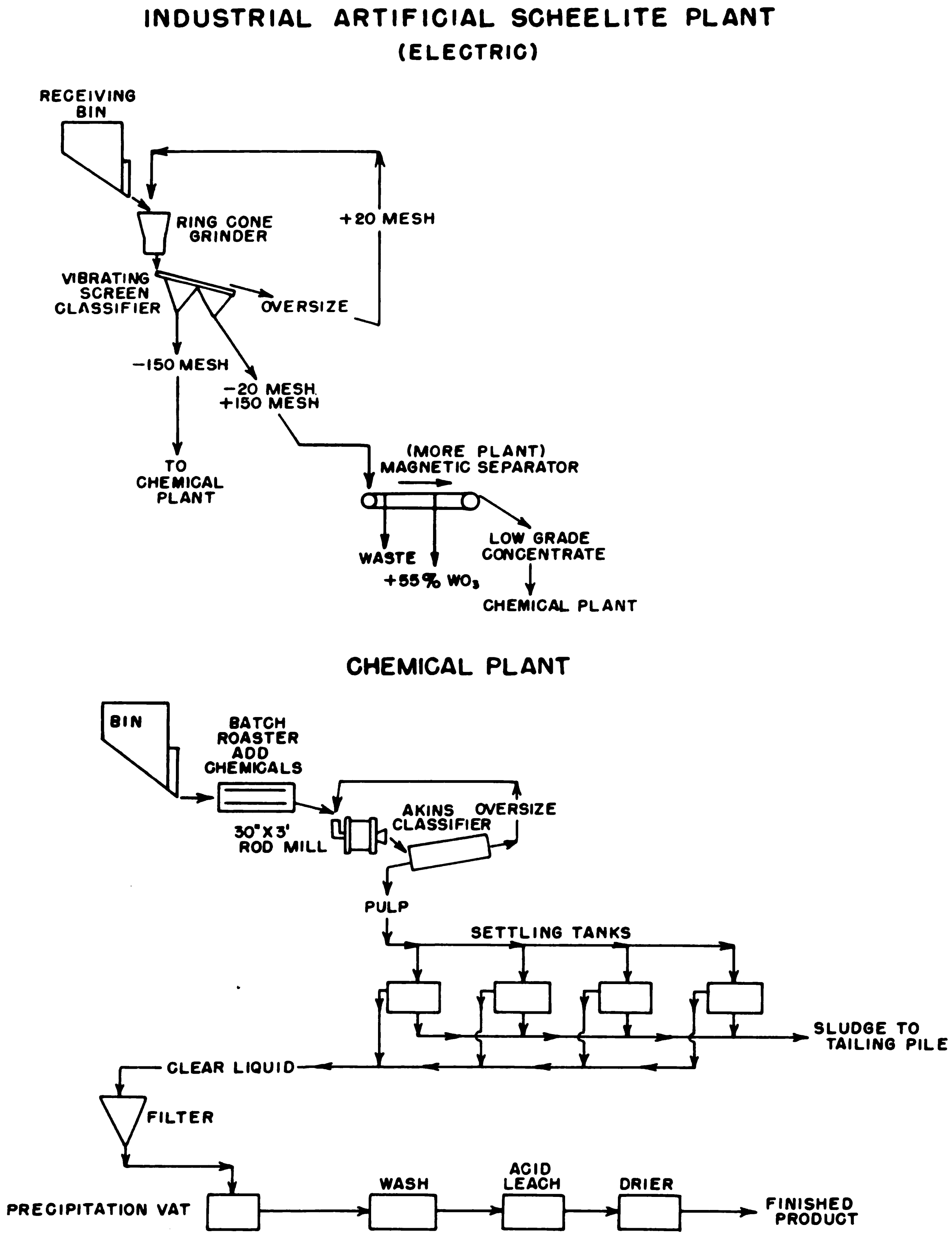


Figure 13. - Flowsheet of Industrial synthetic scheelite plant, Boulder County, Colo.

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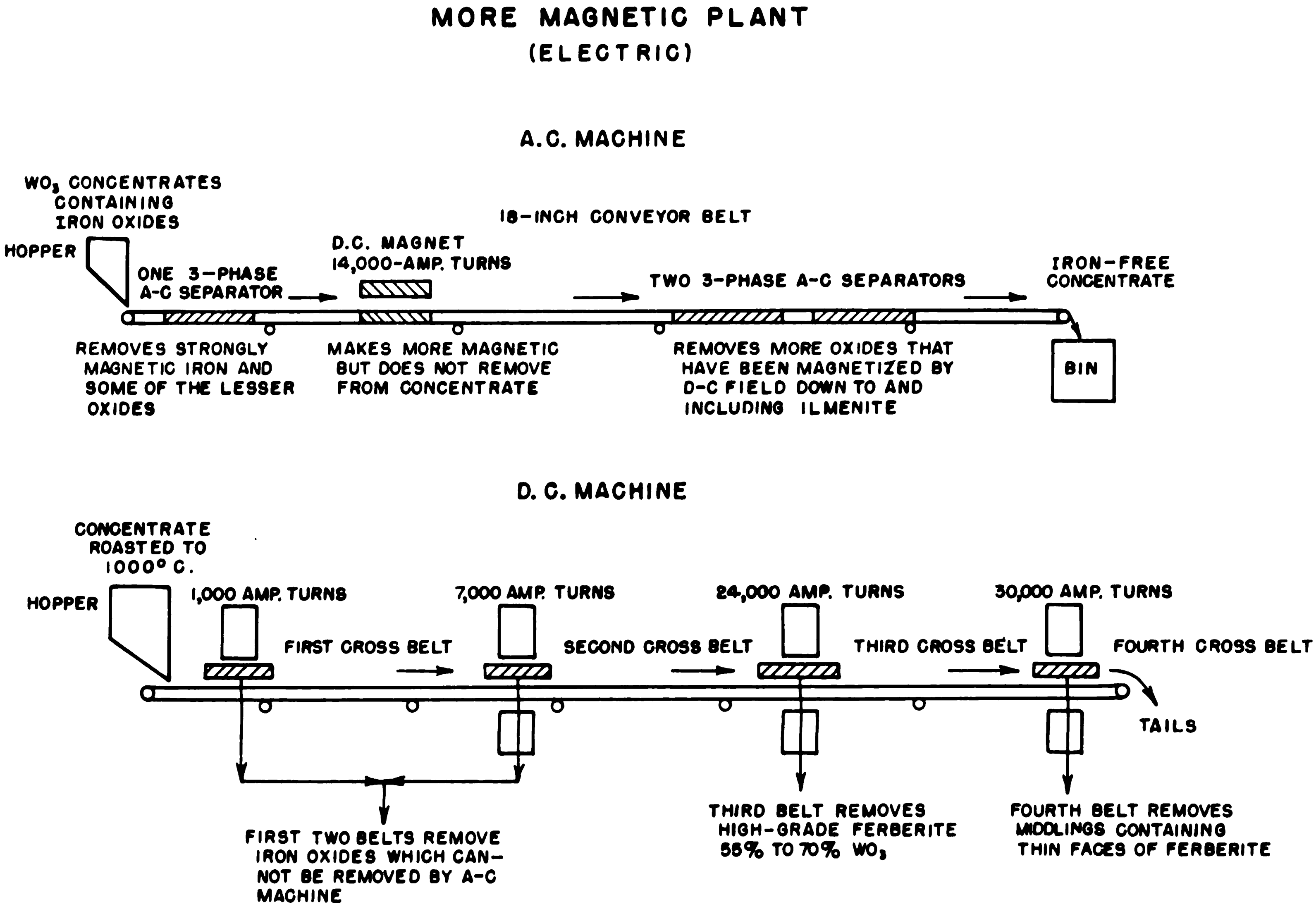

MORE MAGNETIC PLANT
(ELECTRIC)
A.C. MACHINE
WO_3 CONCENTRATES CONTAINING IRON OXIDES
HOPPER
18-INCH CONVEYOR BELT
ONE 3-PHASE A-C SEPARATOR
D.C. MAGNET 14,000-AMP. TURNS
TWO 3-PHASE A-C SEPARATORS
IRON-FREE CONCENTRATE
REMOVES STRONGLY MAGNETIC IRON AND SOME OF THE LESSER OXIDES
MAKES MORE MAGNETIC BUT DOES NOT REMOVE FROM CONCENTRATE
REMOVES MORE OXIDES THAT HAVE BEEN MAGNETIZED BY D-C FIELD DOWN TO AND INCLUDING ILMENITE
BIN
D. C. MACHINE
CONCENTRATE ROASTED TO 1000° C.
HOPPER
1,000 AMP. TURNS
7,000 AMP. TURNS
24,000 AMP. TURNS
30,000 AMP. TURNS
FIRST CROSS BELT
SECOND CROSS BELT
THIRD CROSS BELT
FOURTH CROSS BELT
TAILS
FIRST TWO BELTS REMOVE IRON OXIDES WHICH CANNOT BE REMOVED BY A-C MACHINE
THIRD BELT REMOVES HIGH-GRADE FERBERITE 55% TO 70% WO_3
FOURTH BELT REMOVES MIDDLINGS CONTAINING THIN FACES OF FERBERITE

Figure 14. - Flowsheet of the More magnetic tungsten plant, Boulder County, Colo.

Scavenging Plants for Dump Ore

From the beginning of ferberite mining in the area the richer sections of dumps have been jigged near the dump site or treated in local mills. A number of dumps have been entirely reworked. The Rogers No. 1 dump, averaging 0.99 percent WO_3, was shipped to the Government stockpile during World War II. A few dumps contain considerable tungsten but are not available for leasing at the present time. Harrison Cobb, who has successfully reworked several dumps in the district, divides the dumps into two groups - those that are virtually barren of tungsten and those that will yield 0.2 percent WO_3. Part of this latter group of dumps, which are too low-grade for processing at local mills were reworked during 1953 by scavenging operations, which included screening to 1 inch or 1-1/2 inches, passing through a riffle box, and either jigging the riffle concentrates or passing over scalping jigs and rejigging the scalping jig concentrate. Low-grade stope fills that have also been treated in these plants are listed in table 5.

TABLE 5. - Scavenger plants operated in 1953

Plant	Type	Figure number	Capacity per hour	Tons treated in 1953
Cobb-Weldon	Scalper jigs (4)	15	8	10,038
Pastore	Scalper sluice boxes (2)	16	10	10,000
Linder	Scalper sluice box	16	10	12,000
Ford	Scalper jig	-	2	3,000

On test runs the Cobb-Weldon plant has made a 43-percent recovery on horn ore and 64 percent recovery on soft ore.

Flowsheets of the Cobb-Weldon, Pastore, and Linder scavenging plants are shown on figures 15 and 16.

Sorting Plants

Sorting plants have been installed at several of the mines. The mine-run ore is generally screened and the coarse material washed and sorted. A flowsheet of the Cold Spring sorting plant is shown on figure 17.

Float Beds

During the 1900's a number of rich float beds were worked by hand; the overburden was screened and the oversize handpicked. The screened material was jigged. During the past 10 years a large area, mostly along stream beds, has been worked with placer machines, but no operations of this type were carried on during 1953. A small amount of float was produced from beds near the Pansy Blossom, Orange Blossom, and Clyde mines. An area south of the Cold Spring mine reportedly has a content valued at $4.00 per ton in recoverable tungsten over an area 1,500 feet long, 1,000 feet wide, and 3 feet deep. Cold Springs Tungsten, Inc., plans to work this float bed during 1954.

Tungsten operators in Boulder County recognize the need for improved mill recovery on the soft ores and for additional metallurgical research on the horn ores. There is little chance that gravity concentration can be improved to a degree that will be of much benefit. The development of a suitable flotation reagent, which will float the ferberite without floating the quartz, would help improve recoveries.

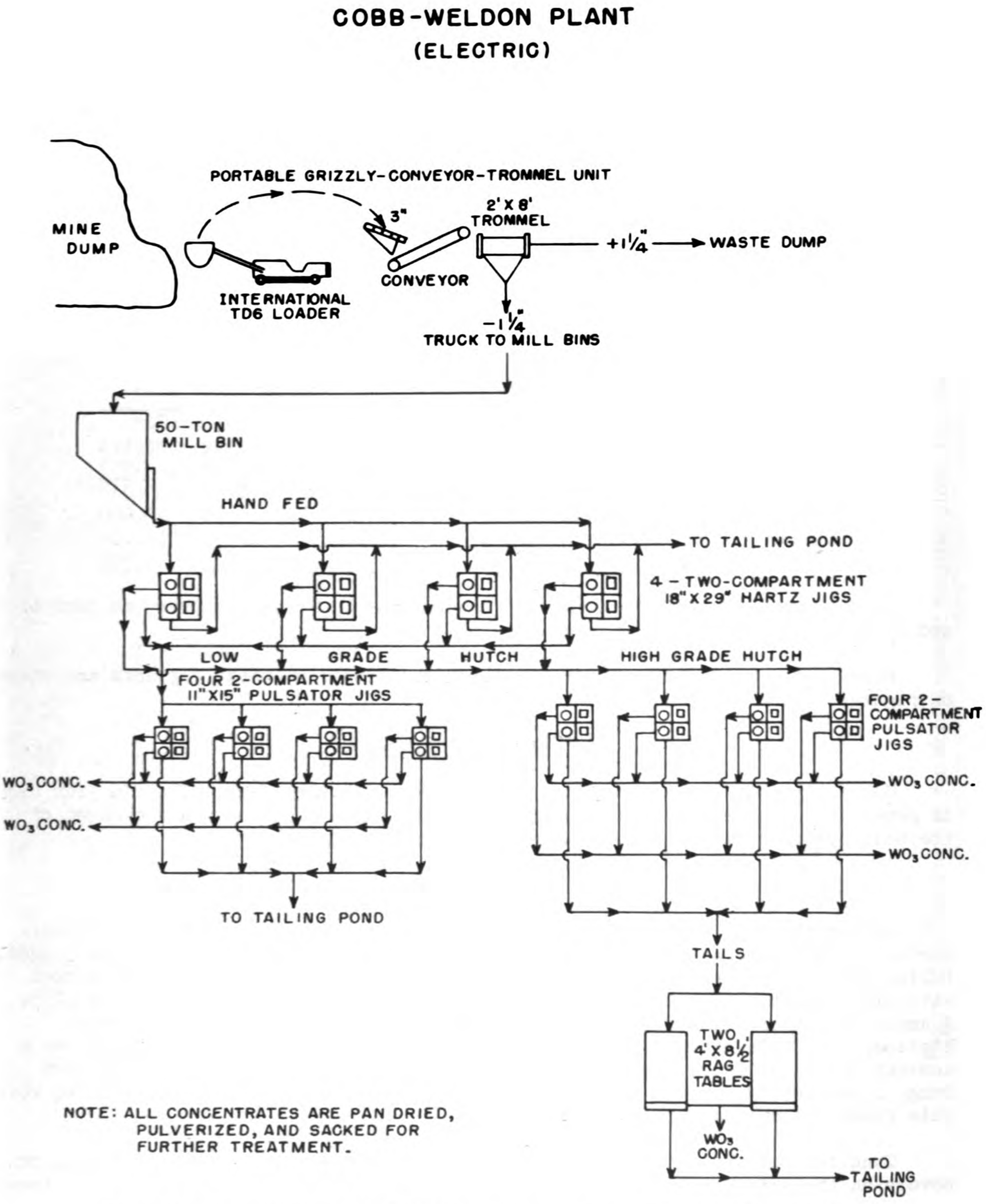
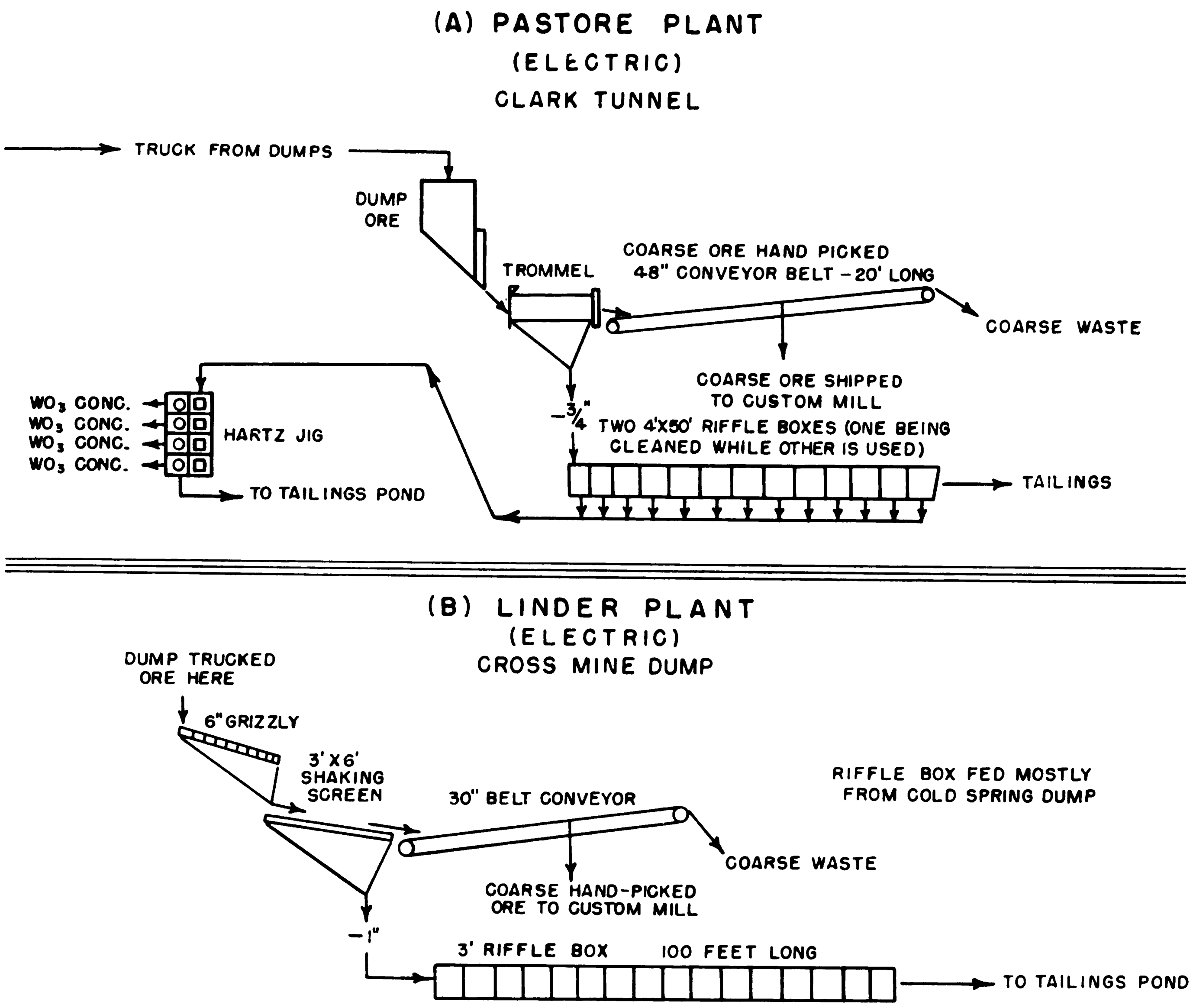


Figure 15. - Flowsheet of the Cobb-Weldon tungsten plant, Boulder County, Colo.



RIFFLE CONCENTRATES WASHED INTO A THREE-COMPARTMENT HARTZ-TYPE JIG

Figure 16. - Flowsheet of the Pastore and Linder tungsten plants, Boulder County, Colo.

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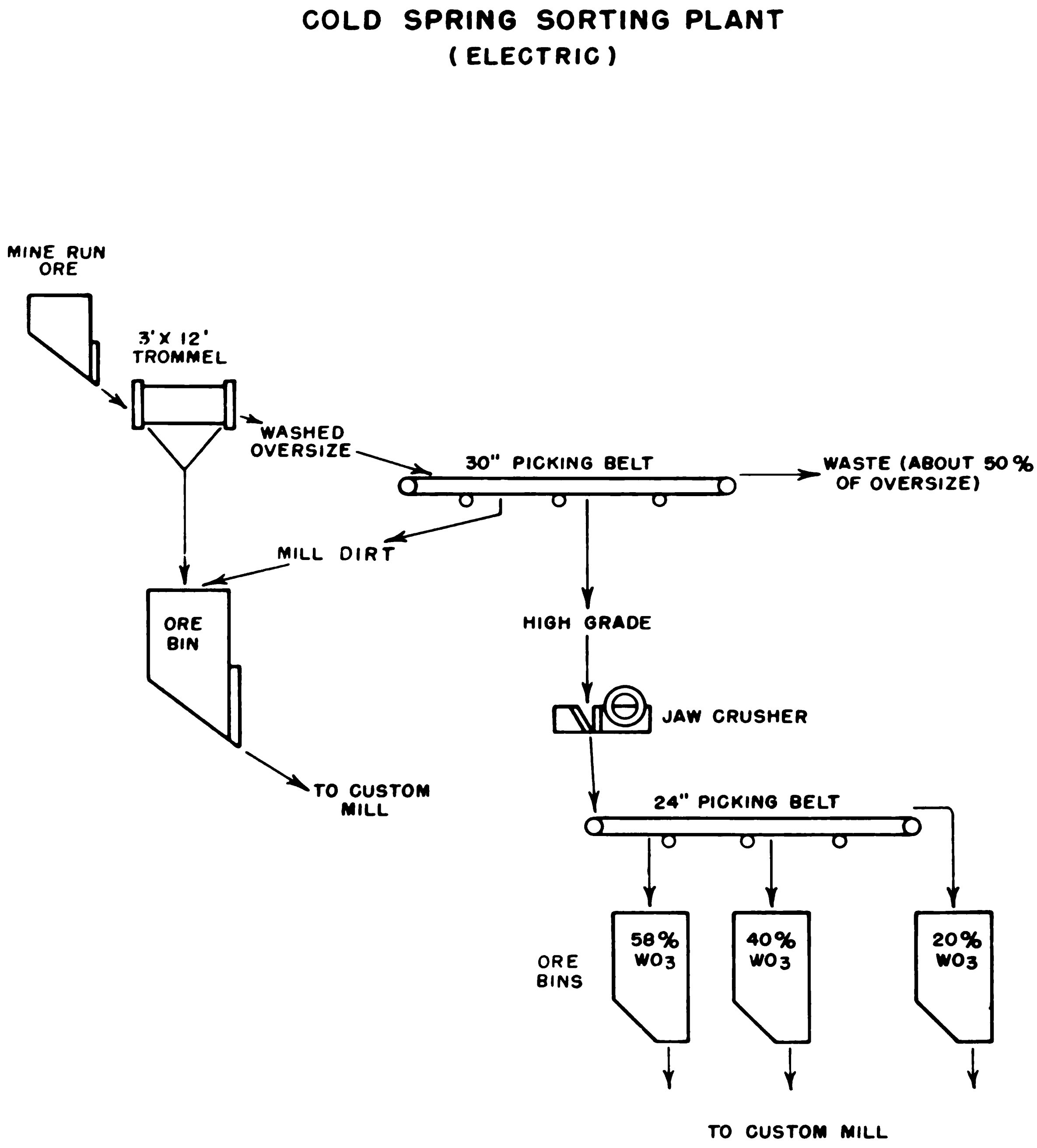

Figure 17. - Flowsheet of the Cold Spring sorting plant, Boulder County, Colo.

The results shown by the More magnetic-separation plant indicates that iron-laden concentrates can be cleaned to a marketable grade, and the operators of the district hope that the synthetic scheelite plant being constructed by the Industrial Engineering & Supply Co. will solve most of their low-grade concentrate and middling problems.

USES FOR TUNGSTEN

The chief uses of tungsten are for making tungsten carbide, chemical compounds, and metallurgical alloys. Tungsten carbide has a hardness of 9 on the Mohr scale, and tungsten steels have the very useful property of retaining their hardness up to a red heat, and can, therefore, be used at much higher speeds and for heavier cuts than ordinary tool steels. Tungsten is also used as filaments in electronic tubes.

The principal uses are summarized as follows:

1. Carbides (WC and W_2C)
    - Sintered, with or without other carbides (armor-piercing shells, high-speed tools, rock-drill bits)
    - Fused, with or without other carbides (hard facing)
    - Crystals, with or without other carbides (small production)
2. Chemicals
    - Chemical compounds
    - Colors and inks
    - Miscellaneous
3. Ferrous alloys
    - Die steels
    - Hot work steels
    - High speed steels, tool steels
4. Nonferrous alloys
    - Cutting tool alloys
    - Resistance welding alloys
    - Electric contact alloys
    - Jet engine alloys
    - Miscellaneous alloys
5. Metallic tungsten
    - Wire (lamp filaments, electronics)
    - Rod (welding, distributor points)
    - Sheet (shielding radio-active material)
    - Powder (tungsten carbide)

GENERAL REVIEW OF THE TUNGSTEN SITUATION

During the early 1900's Boulder County, Colo., and the Atolia district in California produced the major portion of the world's supply of tungsten. Later considerable tungsten was recovered by placer operations in southeastern Asia, and in 1917, China became the leading producer. In 1950 the leading producers were China with 28 percent, United States with 13 percent, Burma with 12 percent, Bolivia with 9 percent, Portugal with 7 percent, and Korea with 6 percent.

Tungsten is a strategic mineral in time of war. The need for tungsten for armor-piercing shells, tool steel, jet engines, tungsten carbide and other uses

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greatly increases in time of national emergency. Domestic production in 1951 was less than 6,000,000 pounds of tungsten and the foreign free world production was about 19,500,000 pounds. The free world tungsten reserves (not including United States) are estimated as 380,000,000 pounds, and at the 1951 rate of consumption domestic reserves would last about 10 years if no additional ore was developed. The probable United States consumption of tungsten for 1975 has been estimated by the President's Materials Policy Commission as 16,500,000 pounds.

It is generally recognized that domestic producers cannot profitably compete with foreign sources of supply under ordinary conditions. It is also generally concluded that large stocks should be maintained in case of a national emergency.

The outlook for an ample supply of tungsten for the United States is uncertain. Efforts should be made to increase our knowledge on the extent of domestic tungsten deposits and methods of recoverying tungsten from the ores.

In Boulder County the indicated and inferred reserves of soft and horn ore contain an estimated 358,742 units of tungsten trioxide. Allowing for 70-percent recovery, these reserves are equivalent to about 17 percent of the past production of the district. Considering the many hundreds of locations from which tungsten has been produced and the relatively small amount of development work that has been done, especially on veins prospected less than 100 feet deep, a future production of one-half the past production appears possible.

Many of the metallurgical problems encountered in upgrading ferberite ores are unique to this district. Research toward improving recovery of ferberite, such as testing new flotation reagents and roasting or treating horn ore before fine grinding, might result in increased production and new discoveries of substantial importance.

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APPENDIX I

Estimated Tungsten Production by Years in Boulder County, Colo.

Year	Units	Average price per short ton unit of WO_3, in dollars	Remarks
1900	2,760	1.25	)
1901	4,200	2.58	)
1902	11,540	3.08	) Number of units uncertain.
1903	13,800	2.49	)
1904	22,800	4.12	) Wolf tongue mill operating.
1905	36,400	5.57	)
1906	43,500	6.26	)
1907	68,760	9.04	First tungsten boom.
1908	35,040	5.71	
1909	59,580	6.32	
1910	73,260	7.68	Lakewood mill finished.
1911	43,800	5.97	
1912	48,720	6.27	Atolia mine in California became largest individual producer in world.
1913	57,180	7.24	Primas and Wolf Tongue properties are largest producers in Boulder County.
1914	28,020	7.32	Atolia mine in California outproduced Boulder County.
1915	57,780	29.30	Miners' wages increased to 45 cents per hour.
1916	144,060	33.98	Colorado leading producer in United States.
1917	162,420	18.40	California leading producer in United States.
1918	114,600	23.24	Imports of tungsten start from China.
1919	7,800	18.02	Vasco mine leading producer in Boulder County.
1920	12,960	7.86	Vasco and Wolf Tongue principal producers in Boulder County.
1921	None	-	No tungsten produced in United States.
1922	None	-	Wolf Tongue Co. kept water out of Cold Spring mine.
1923	14,460	10.00	Tongue mine.
1924	1,500	8.47	Wolf Tongue only company mining in Boulder County.
1925	12,060	10.57	
1926	13,920	11.10	
1927	19,920	10.37	
1928	13,740	10.40	
1929	9,120	13.13	
1930	2,820	12.09	New ore shoot found in Cold Spring mine.
1931	5,880	11.02	
1932	Production very small	9.20	Wolf Tongue and Cowdery only operators.
1933	5,160	9.58	
1934	20,520	14.57	Mostly from leasing operators, Mammoth mine.
1935	31,140	13.37	Cold Spring and Mammoth mines.
1936	10,816	14.00 to 16.00	Gold, Silver, and Tungsten, Inc., and Wolf Tongue Co. shipping.
1937	13,144	16.00 to 35.00 to 22.00	Do.
1938	14,418	18.00?	Gold, Silver, and Tungsten, Inc., principal shipper, Illinois mine operated 3 months V.C.A. Bldg. Conger mill.
1939	28,746	17.11	Good ore discovered in Illinois mine shaft.
1940	43,559	18.00	Miners' wages $4.00 per day.
1941	38,740	23.41	Includes small amounts from San Juan and Summit Counties.
1942	22,810	24.12	Includes small amounts from San Juan and Summit Counties, Miners' wages 80 cents an hour.
1943	20,522	25.07	Mostly Wolf Tongue and V.C.A.
1944	17,955	23.36	Mostly Wolf Tongue, Miners' wages 90 cents per hr.
1945	15,136	23.21	Vanadium Corp. discontinued operating in May.
1946	12,473	20.17	
1947	3,678	25.77	
1948	1,839	26.27	Climax Molybdenum mine in Lake County, Colo., begins production.
1949	96	26.38	United States production off 25 percent.
1950	539	14.00 to 22.00	
1951	3,258	22.00 to 63.00	Defense Minerals Exploration Administration grants loans.
1952	6,683	63.00	Cold Spring mine main producer.
1953	19,143	63.00	Do.
	1,472,775		

APPENDIX II

Purchase Schedule for Tungsten Ores by Hetzer Mines, Inc.
Effective - November 16, 1953
(Subject to change without notice)

Schedule "A"

Grade, percent	Price per unit of WO_3	Grade, percent	Price per unit of WO_3	Grade, percent	Price per unit of WO_3
1	$23.00	20	$34.20	41	$39.50
1.5	25.00	21	34.50	42	39.70
2	27.00	22	34.70	43	40.00
2.5	28.50	23	35.00	44	40.20
3	30.00	24	35.20	45	40.50
4	32.00	25	35.50	46	40.70
5	33.00	26	35.70	47	41.00
6	33.60	27	36.00	48	41.20
7	34.20	28	36.20	49	41.50
8	34.60	29	36.50	50	50.00
9	34.90	30	36.70	51	52.00
10	35.20	31	37.00	52	54.00
11	35.50	32	37.20	53	55.00
12	35.80	33	37.50	54	56.00
13	36.10	34	37.70	55	57.00
14	36.20	35	38.00	56	57.50
15	36.00	36	38.20	57	58.00
16	35.80	37	38.50	58	58.50
17	35.40	38	38.70	59	59.00
18	35.00	39	39.00	60	60.00
19	34.60	40	39.20		

Schedule "B" (Silicate or "horn" ores)

Same as schedule "A" above less $4.00 per unit.

Notes:

1. The schedule to apply to an ore will be determined by the degree to which the following impurities are eliminated by simple concentration and by the extent to which the WO_3 concentrates must be chemically treated for which a special charge will be made. The classification by our mill superintendent will be final. The following is a list of the undesirable impurities:

Copper	(Cu)	Bismuth	(Bi)	Antimony	(Sb)
Phosphorus	(P)	Molybdenum	(Mo)	Manganese	(Mn)
Arsenic	(As)	Tin	(Sn)	Lead	(Pb)
Sulphur	(S)	Zinc	(Zn)		

2. Ore below 1 percent accepted by special arrangement only.

3. Other than ferberite ore accepted by special arrangement only.

4. Ore previously milled accepted by special arrangement only.

5. A sampling charge of $20.00 will be made on all lots of less than $250.00 gross value.

APPENDIX III

Electric Power Rates of the Public Service Co. of Colo. (Applying to the tungsten area as of March 1954)

Schedule 210 Special Secondary; Urban, Fringe, and Rural

Available for 3-phase, alternating current power service and incidental lighting, provided the total amount of service does not exceed 150 kilovolt-amperes.

Rate

Minimum charge per month for:	Dollars
The first 25 hp. of demand, per hp.	1.50
All additional hp. of demand, per hp. which minimum charge includes a use of 30 kw.-hr. per hp. of demand	1.00
Next 60 kw.-hr. used per month, per hp. of demand, but not less than 450 kw.-hr., per kw.-hr.	.03
All additional kw.-hr. per month, per kw.-hr.	.01
Plus a surcharge for incidental connected lighting load of over 10 percent of power demand per 100 watts of such excess lighting load	.20
Minimum charge as specified in rate, but not less per month than	15.00

Schedule 212 General Primary Power

Applicable only to 3-phase primary power service

Rate

Demand charge:	Dollars
First 50 kw. or less of demand, per month	115.00
Next 200 kw. of demand, per month, per kw.	1.65
Next 200 kw. of demand, per month, per kw.	1.35
All additional	1.10
Energy charge:	
First 100 kw.-hr. used per month, per kw. of demand, per month	.012
Next 5,000 kw.-hr. used per month, per kw.-hr.	.01
Next 60,000 kw.-hr. used per month, per kw.-hr.	.007
Next 120,000 kw.-hr. used per month, per kw.-hr.	.006
All additional kw.-hr. used per month, per kw.-hr.	.0055
Minimum charge not less than	200.00

APPENDIX IV

Principal Tungsten Mines in Boulder County, Colo.
(Including outlying mines)

A. Predominantly soft ore mines having a production of over 100,000 units of WO_3

Mine	Present owner	Location		
		Sec.	T.	R.
1. April Fool-Good Friday	George Jump	36	1 N.	72 W.
2. Beddig	Colorado Tungsten Corp.	11	1 S.	73
3. Cold Spring #1	Hetzer Mines, Inc.	7-8	1 S.	72 W.
4. Conger	Vanadium Corp. of America	11	1 S.	73 W.

B. Predominantly soft ore mines having a production of between 10,000 and 100,000 units of WO_3

Mine	Present owner	Location		
		Sec.	T.	R.
1. Bonanza #2	Hetzer Mines, Inc.	5-8	1 S.	72 W.
2. Clyde	do.	7	1 S.	72 W.
3. Cross #1	do.	8	1 S.	72 W.
4. Dorothy and Katy	Robert C. and Annabelle Teal Barr	29-32	1 N.	71 W.
5. Elsie	W. L. Tanner and Son	19	1 S.	72 W.
6. Eureka	Juanita Clark	35	1 N.	72 W.
7. Hoosier	Hetzer Mines, Inc.	7	1 S.	72 W.
8. Illinois	do.	11	1 S.	73 W.
9. Lone Tree	Vanadium Corp. of America	12	1 S.	73 W.
10. Luckie 2	County of Boulder	36	1 N.	72 W.
11. Mammoth	W. L. Tanner and Son	19	1 S.	72 W.
12. Oregon	Vanadium Corp. of America	33-34	1 N.	72 W.
13. Phillip Extension	Colorado Tungsten Corp.	12	1 S.	73 W.
14. Quaker	Vanadium Corp. of America	34	1 N.	72 W.
5. Quay	Colorado Tungsten Corp.	11	1 S.	73 W.
16. Rake Off	Vanadium Corp. of America	12	1 S.	73 W.
17. Rambler	George Cowdery	24	1 S.	73 W.
18. Rogers #3	Platt Rogers Estate	3	1 S.	72 W.
19. Smith	Colorado Tungsten Corp.	36	1 N.	72 W.
20. Tungsten	George Cowdery	19	1 S.	72 W.
21. Vasco #5	Hetzer Mines, Inc.	8	1 S.	72 W.
22. Vasco #6	do.	8	1 S.	72 W.
23. Vasco #7	do.	8	1 S.	72 W.
24. Vasco #10	do.	8	1 S.	72 W.
25. Western Star	do.	7	1 S.	72 W.

C. Predominantly soft ore mines having a production of between 1,000 and 10,000 units of WO_3

Mine	Present owner	Location		
		Sec.	T.	R.
1. Anna L.	Joseph Rafter	36	1 N.	72 W.
2. Balmoral	Colorado Tungsten Corp.	36	1 N.	72 W.
3. Barkers #1,#2,#3,#4	J. Clark-Hanna Barker Estate	17-18	1 S.	72 W.
4. Big Six	Richard Tatlow	13	1 S.	73 W.
5. Black Hawk	George Cowdery	24	1 S.	73 W.
6. Black Iron	Sam D. Walters	19	1 S.	72 W.
7. Black Jack #1 & #2	Hetzer Mines, Inc.	5	1 S.	72 W.
8. Black Rose	R. E. Dalley	4	1 S.	72 W.
9. Black Rover	George Cowdery	20	1 S.	72 W.
10. Blue Bell Group	Vanadium Corp. of America	4	1 S.	72 W.
11. Bob Cat	do.	12	1 S.	73 W.
12. Bonanza #1	Hetzer Mines, Inc.	5	1 S.	72 W.
13. Brace Tract	Robert H. Sayre	24	1 S.	73 W.
14. Catastrophe	Mattie M. Lawrence	35	1 N.	72 W.
15. Cold Spring #2	Hetzer Mines, Inc.	8	1 S.	72 W.
16. Cold Spring #3	do.	8	1 S.	72 W.
17. Cork Screw	Vanadium Corp. of America	12	1 S.	73 W.
18. Crow #1 and #1-3/4	Colorado Tungsten Corp.	12	1 S.	73 W.
19. Crow #4	do.	12	1 S.	73 W.
20. Crow #7 and #8	do.	12	1 S.	73 W.
21. Crow #11	do.	12	1 S.	73 W.
22. Crow #18	do.	12	1 S.	73 W.
23. Crow #37	do.	12	1 S.	73 W.
24. Crow Miscl.	do.	11-12	1 S.	73 W.
25. Dillon	Hetzer Mines, Inc.	7	1 S.	72 W.
26. Double Header group	Vanadium Corp. of America	8	1 S.	72 W.
27. Faircount	C. L. Stubbs	36	1 N.	72 W.
28. Fitzsimmons #1	W. L. Tanner and Son	19	1 S.	72 W.
29. Fitzsimmons #2	do.	19	1 S.	72 W.
30. Forest Home	Hetzer Mines, Inc.	7	1 S.	72 W.
31. Gale	do.	7	1 S.	72 W.
32. Gale Extension	Colorado Tungsten Corp.	12	1 S.	73 W.
33. Gem	Hetzer Mines, Inc.	7-8	1 S.	72 W.
34. Georgia A	do.	7	1 S.	72 W.
35. Grey Back	Vanadium Corp. of America	11	1 S.	73 W.
36. Greenhorn Tunnel	Colorado Tungsten Corp.	12	1 S.	73 W.
37. Hildegard	Vanadium Corp. of America	34	1 N.	72 W.
38. Hillside	do.	34	1 N.	72 W.
39. Jack and Summit	Hetzer Mines, Inc.	7	1 S.	72 W.
40. Kicker	do.	8	1 S.	72 W.
41. Last Chance #2	do.	7	1 S.	72 W.
42. Lily	do.	7	1 S.	72 W.
43. Lincoln Group	James McGlaghen	30	1 N.	71 W.

C. Predominantly soft ore mines having a production of between 1,000 and 10,000 units of WO_3 (Con.)

Mine	Present owner	Location		
		Sec.	T.	R.
44. Logan group	Logan Metals Co.	19	1 N.	72 W.
45. Long Tunnel	Unknown	34	1 N.	72 W.
46. Lookout	Donald Brotzman	36	1 N.	72 W.
47. Manchester	Strolle Brothers	32	1 S.	72 W.
48. Manion Lease	Hetzer Mines, Inc.	5-8	1 S.	72 W.
49. Mill Sump	do.	13	1 S.	72 W.
50. Miser group	Vanadium Corp. of America	34	1 N.	72 W.
51. Nancy Henderson	Ernest Bonelli	7	1 S.	72 W.
52. Ohio	Vanadium Corp. of America	29	1 N.	71 W.
53. Ophir	do.	34	1 N.	72 W.
54. Orange Blossom	Hetzer Mines, Inc.	7-8	1 S.	72 W.
55. Oregon	do.	11	1 S.	73 W.
56. Pansy Blossom	do.	8	1 S.	72 W.
57. Pennsylvania	J. Jordan et al.	34	1 N.	72 W.
58. Pewink	Not patented	34	1 N.	72 W.
59. Philadelphia	W. D. Townsend	8	1 S.	72 W.
60. Philadelphia and N. Y.	Hetzer Mines, Inc.	8	1 S.	72 W.
61. Phillip	do.	7	1 S.	72 W.
62. Pioneer	Robert H. Sayre	24	1 S.	73 W.
63. Post (Evening)	Mattie M. Lawrence	35	1 N.	72 W.
64. Princess	Homer Pennock	29	1 N.	71 W.
65. Prospect Tunnel	Hetzer Mines, Inc.	7	1 S.	72 W.
66. Pueblo Belle	Shattuck Chemical Co.	31	1 N.	71 W.
67. Red Signe	Annabelle Teal Barr	32	1 N.	71 W.
68. Rocky Mountain	E. J. Rodke	4	1 S.	72 W.
69. Rogers #1	Platt Rogers estate	3	1 S.	72 W.
70. Rogers #5	do.	3	1 S.	72 W.
71. Rogers #7	do.	3	1 S.	72 W.
72. Rogers #11	do.	3	1 S.	72 W.
73. Roosevelt	Joseph Rafter	36	1 N.	72 W.
74. Silver Queen	Victor Helberg	8	1 S.	72 W.
75. Spider Leg	Vanadium Corp. of America	11	1 S.	73 W.
76. Sunday	George Cowdery	19	1 S.	72 W.
77. Tenderfoot #1	Hetzer Mines, Inc.	8	1 S.	72 W.
78. Tenderfoot #2	do.	7	1 S.	72 W.
79. Tennessee	Joseph Smith	24	1 S.	73 W.
80. Town Lot	Hetzer Mines, Inc.	13	1 S.	73 W.
81. Trevarton Ranch	do.	8	1 S.	72 W.
82. Vasco #1 and #1-1/2	do.	8	1 S.	72 W.
83. Vasco #2	do.	8	1 S.	72 W.
84. Vasco #3	do.	8	1 S.	72 W.
85. Vasco #4	do.	8	1 S.	72 W.
86. Vasco #8	do.	8	1 S.	72 W.

D. Predominantly soft ore mines having a production of less than 1,000 units of WO_3

Mine	Present owner	Location		
		Sec.	T.	R.
1. Alley Bird	W. Perkins	Unknown		
2. Anna C.	O. B. Scott	11	1 S.	73 W.
3. Anna #1 & #2	Hetzer Mines, Inc.	11	1 S.	73 W.
4. Arrow #1 and #2	do.	7	1 S.	72 W.
5. Arrow #3	do.	7	1 S.	72 W.
6. Big Chief	Stolle and DeBell	Gilpin County		
7. Black Beauty	Hetzer Mines, Inc.	5	1 S.	72 W.
8. Black Gold	W. Perkins	Gilpin County		
9. Black Hawk	Hetzer Mines, Inc.	5	1 S.	72 W.
10. Black Pearl	do.	5	1 S.	72 W.
11. Bueno	Harry M. Williamson	24	2 N.	71 W.
12. Byron (Lord)	L. V. Davidson	35	1 N.	72 W.
13. Cameran	Hetzer Mines, Inc.	7	1 S.	72 W.
14. Carlberg	do.	5-8	1 S.	72 W.
15. Chahauhau	W. Perkins	Gilpin County		
16. Cold Spring #4	Hetzer Mines, Inc.	8	1 S.	72 W.
17. Cracker Jack	Margaret L. Peters	4	1 S.	72 W.
18. Crete	Anabelle Teal Barr	29-32	1 N.	71 W.
19. Cross #2	Hetzer Mines, Inc.	8	1 S.	72 W.
20. Crow #2 & #3	Colorado Tungsten Corp.	12	1 S.	73 W.
21. Crow #12	do.	12	1 S.	73 W.
22. Crow #36	do.	12	1 S.	73 W.
23. Daisy	Hetzer Mines, Inc.	5	1 S.	72 W.
24. Denver	do.	13	1 S.	73 W.
25. Durkin	James Durkin	34	1 N.	72 W.
26. East View	Not patented	20	1 S.	72 W.
27. Edith Mary	Hetzer Mines, Inc.	7	1 S.	72 W.
28. Fire Cracker	do.	5	1 S.	72 W.
29. Fraction	Vanadium Corp. of America	34	1 N.	72 W.
30. Germania #1	Hetzer Mines, Inc.	8	1 S.	72 W.
31. Germania #2	do.	8	1 S.	72 W.
32. Glacier Lake	A. B. Pace	30	1 N.	72 W.
33. Graphic	Dora Fairhurst	5	1 S.	71 W.
34. Highway	Colorado State Highway Comm.	8	1 S.	72 W.
35. Holy Cross	Hetzer Mines, Inc.	5	1 S.	72 W.
36. Horrible Gash	do.	5	1 S.	72 W.
37. Hugo #1 and #2	Alton Stinson	5	1 S.	72 W.
38. Hummer	Hetzer Mines, Inc.	7	1 S.	72 W.
39. Iowa	Vanadium Corp. of America	34	1 N.	72 W.
40. June	George Todd	36	1 N.	72
41. Lady Luck	Albert Rogers	34	1 N.	72 W.
42. Last Chance #1	Hetzer Mines, Inc.	7	1 S.	72 W.
43. Little Charlie	do.	13	1 S.	73 W.
44. Little Jap	do.	7	1 S.	72 W.
45. Little Lester	G. R. Anderson	36	1 N.	72
46. Lone Jack	Hetzer Mines, Inc.	7	1 S.	72 W.
47. Lone Pine	Vanadium Corp. of America	11	1 S.	73 W.
48. Lonesome Polecat	Richard Tatlow	13	1 S.	73 W.
49. Mac Group	A. J. Critz	31	1 N.	71 W.
50. Madeline	Hetzer Mines, Inc.	8	1 S.	72 W.

D. Predominantly soft ore mines having a production of less than 1,000 units of WO_3 (Con.)

Mine	Present owner	Location		
		Sec.	T.	R.
51. Mary Nelson	W. L. Tanner and Son	19	1 S.	72 W.
52. Minnesota	Hetzer Mines, Inc.	24	1 S.	73 W.
53. Missing Link	George Cowdery	24	1 S.	73 W.
54. Do.	Hetzer Mines, Inc.	7	1 S.	72 W.
55. Minnie Foy	D. H. Petzke	11	1 S.	73 W.
56. Moonrise	John Taylor	Gilpin County		
57. Niagra	Patterson Estate	13	1 S.	73 W.
58. 1905	Hetzer Mines, Inc.	7	1 S.	72 W.
59. No name	do.	5	1 S.	72 W.
60. Only Chance	do.	7	1 S.	72 W.
61. Parker	Joseph Rafter	36	1 N.	72 W.
62. Paymaster	Paymaster Mine Trust	31	1 N.	72 W.
63. Pick and Gad	Cecil Jones	7	1 S.	72 W.
64. Pine Shade	Nannie L. Duval	15	1 S.	73 W.
65. Pleasant Dream	Colorado Tungsten Corp.	36	1 N.	72 W.
66. Protection	Gold Uranium Mining Co.	34	1 N.	72 W.
67. Queen (Golden)	Joseph Walters	6	1 N.	72 W.
68. Rainy Day	Hetzer Mines, Inc.	8	1 S.	72 W.
69. Red Pine	do.	7	1 S.	72 W.
70. Reeves Patent	Jas. W. Keady et al.	8	1 S.	72 W.
71. Richard	Colorado Tungsten Corp.	12	1 S.	73 W.
72. Rogers #2	Platt Rogers estate	3	1 S.	73 W.
73. Rogers #4	do.	3	1 S.	73 W.
74. Rogers #6	do.	3	1 S.	73 W.
75. Rogers #8	do.	3	1 S.	73 W.
76. Rogers #9	do.	3	1 S.	73 W.
77. Rogers #10	do.	3	1 S.	73 W.
78. Rogers Miscl.	do.	2-3-4 & 9	1 S.	72 W.
79. Romancier	Not patented	17	2 N.	71 W.
80. Rudy #2	Elmer Rudine	34	1 N.	72 W.
81. Silver Bell	James Durkin	5	1 S.	73 W.
82. Silver King	Albert Perkins	34	1 N.	72 W.
83. Sisson claims	Nannie L. Duval	Various		
84. Spencer Tunnel	Hetzer Mines, Inc.	7	1 S.	72 W.
85. Sunnyside	Bessie I. and C. V. Skinner	21	1 N.	73 W.
86. Steel Plate	Hetzer Mines, Inc.	7	1 S.	72 W.
87. Sunbeam	Fred J. Holmes	19-20	1 N.	71 W.
88. Sunset	Mrs. Duval	11	1 S.	73 W.
89. Tungsten	Hetzer Mines, Inc.	7	1 S.	72 W.
90. Tungsten Mt. #6	George Cowdery	19	1 S.	72 W.
91. Tungsten Mt. #9	do.	19	1 S.	72 W.
92. Utica	Joseph K. Davidson	7	1 N.	72 W.
93. Vacant Spot	Hetzer Mines, Inc.	11	1 S.	73 W.
94. Victor	Milton V. Christman	8	1 S.	72 W.
95. Walker Ranch	Oliver I. and Bertha H. Taylor	28	1 S.	71 W.
96. Western Cross	Hetzer Mines, Inc.	24	1 S.	73 W.
97. Wild Tiger	A. B. Pace	35-36	1 N.	72 W.
98. Wisconsin	Edward Bonelli	11	1 S.	73 W.
99. World	Hetzer Mines, Inc.	7	1 S.	72 W.

E. Mines producing predominantly horn ore

Mine	Present owner	Location		
		Sec.	T.	R.
1. Amzy	Viola Lancaster	20	1 N.	71 W.
2. Belmont	Mary H. Kettering	5	1 S.	71 W.
3. Black Crystal	L. A. Mock and H. W. Patton	31	1 N.	71 W.
4. Black Prince	do.	31	1 N.	71 W.
5. Blue Jay	W. D. Brown	35	1 N.	72 W.
6. Clyde	Hetzer Mines, Inc.	7	1 S.	72 W.
7. Copeland	(Production over 10,000 units) Vanadium Corp. of America	20	1 S.	71 W.
8. Crown Point	W. Todd Dofflemeyer	9	1 S.	73 W.
9. Eureka	Juanita Clark	35	1 N.	72 W.
10. Gold Lake	James Morgan	4	1 N.	72 W.
11. Grand View	A. C. Hager	8	1 N.	71 W.
12. Great Sphinx	Edward Bonelli	20	1 N.	71 W.
13. Herald	Maude V. Caughlin	35	1 N.	72
14. Helen	John Bosko	30	1 N.	71 W.
15. Home Run	Crucible Steel Co.	6	1 S.	72 W.
16. Kekionga	Dr. Robert Smith	6	1 S.	71 W.
17. Manyon	Manyon and Spence	4	1 N.	72 W.
18. Pennsylvania	J. Jordan et al.	34	1 N.	72 W.
19. Quaker	Vanadium Corp. of America	34	1 N.	72 W.
20. Rogers #1	Platt Rogers estate	3	1 S.	72 W.
21. Rogers #3	do.	3	1 S.	72 W.
22. Rogers #4	do.	3	1 S.	72 W.
23. Rogers #5	do.	3	1 S.	72 W.
24. Rogers #6	do.	3	1 S.	72 W.
25. Rogers #7	do.	3	1 S.	72 W.
26. Rogers #8	do.	3	1 S.	72 W.
27. Rogers #9	do.	3	1 S.	72 W.
28. Rogers #10	do.	3	1 S.	72 W.
29. Tocap	Unpatented	34	1 N.	72 W.
30. Tungsten King	Nellie B. Robb	5	1 S.	71 W.
31. Vasco #10	Hetzer Mines, Inc.	8	1 S.	72 W.
32. W. T. Claims	L. A. Cole	32	1 N.	71 W.